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LARGE TELESCOPES

BY SIR FRANK DYSON, M.A., LL.D., F.R.S.

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THE subject of my address is the use to which astronomers put the beautiful instruments opticians have given them. Astronomy is, of course, a very old science and had made very great strides before the invention of the telescope; a good many of them are summed up in the Copernican system. The complicated movements of the planets, the seasons, were all explained as due to the Earth's revolution round the Sun. But the arguments appealed to the learned and belief in the heliocentric system might still have been confined to mathematicians if Galileo's telescope had not been pointed to the skies. After that was done all doubt quickly vanished. The spots seen on the Sun proved its rotation. So why should not the Earth rotate? Venus was seen to have phases and Jupiter a disc—so these shining points were bodies like the Moon and Earth. Jupiter was seen to have moons which revolved round him and were not left behind as Jupiter travelled round the Sun. So it was no longer difficult to believe that if the Earth went round the Sun the Moon would accompany her and not be left behind. So the Copernican system soon triumphed. Seeing is said to be believing and the telescope is an instrument which largely increases our faculty of vision.

The insertion by Gascoyne of wires in the focal plane of the objective, developing naturally into the micrometer, was perhaps the next great step, in view of its importance in the determination of exact position, but I must not dwell on this nor on the discoveries and improvements in the refracting telescope which are called to mind by the names of Huygens, Dollond, and Ramsden. Perhaps, too, Newton's mistake about the proportionality of dispersion to refraction was a blessing in disguise, for although it delayed the development of the refractor, the reflecting telescope might not have been gradually improved by Gregory, Cassegrain, and Short till we come to William Herschel. In him were combined a spirit of enquiry, an enthusiasm, industry and inventive engineering skill which led to the desire for

the construction of, and continuous observation with, a large telescope. He began by discovering Uranus, the first addition to the planetary system since the time of the Greeks. He went on to make a survey of the stars and to derive from it the form of the sidereal system. Nebulae and double stars were also surveyed and the orbital movement of double stars discovered.

The development of the refractor was delayed by the difficulty of making large discs, especially flints. This was overcome by Guinand who by the end of the eighteenth century was making discs of 6 ins. diameter. As has often been pointed out, the results of Guinand's experience was carried by members of his family or his firm to England, France, and Germany. Guinand himself moved to Munich early in 1805 and joined with Fraunhofer. The genius of Fraunhofer marks an epoch in optical discovery; but the only point I wish to refer to is the telescope he made for Wilhelm Struve at Dorpat. This had an aperture of 9·6 ins. and a focal length of 170 ins., giving a ratio of 17·7. In addition this instrument had the first clock-driven equatorial. In three years 1824 November to 1827 February Struve surveyed the whole sky from the North Pole to declination − 15° (altitude of 16°), and examined no less than 120,000 stars. He observed at the extraordinary rate of seven stars a minute. In the course of this work he detected over 3000 double stars of which only 700 were previously known. These included:

91	with separation	less than		1″·0
314	,,	,,	between 1″·0	and 2″·0
535	,,	,,	,, 2″·0	,, 4″·0
582	,,	,,	,, 4″·0	,, 8″·0.

As the theoretical resolving power of an object glass of this diameter is 0″·5, the excellence of the telescope as well as the skill of the observer must have been of the highest order. I shall speak of these observations later. Struve was given the task of building and directing the Imperial Russian Observatory at Pulkovo. He obtained an equatorial telescope with an object glass of 15 ins. This was the largest refractor in the world in the middle of the nineteenth century. A further survey of the sky for detection of double stars was undertaken by Otto Struve, the son of Wilhelm. He discovered more than 500 new double stars, of which 154 had a separation of less than 1″·0.

Returning again to reflectors, the great telescope of Lord Rosse—a speculum of 6 ft. aperture and of 53 ft. focus—and Mr Lassell's—a speculum of 4 ft. aperture and 39 ft. focus—were the successors of Herschel's great telescopes. With Lord Rosse's telescope nebulae and clusters were examined in detail and it may be interesting to note that an optical power of 6000 was used. Mr Lassell discovered another satellite of Saturn and two of Uranus.

With a smaller telescope of Lord Rosse's—a 3 ft. speculum—his son, the fourth Earl of Rosse, made a series of valuable observations of the heat received from the Moon. From the full moon the amount was found to be 1/80,000 of that received from the Sun. The heat is all reflected from the Sun and it was found that none comes from the dark part of the Moon.

A new development of the reflecting telescope followed Liebig's discovery of the method of silvering glass. The pioneers in this work were Steinheil and Foucault, but the manufacture of reflecting telescopes was soon taken up in England and developed by Browning, Calver, and others.

An amateur astronomer, A. A. Common of Ealing, started to grind a mirror but afterwards obtained in 1878 a mirror from Calver of 36 ins. and after a good many efforts obtained in 1882 a very fine photograph of the Nebula in Orion. This was the beginning of photography of nebulae, at any rate in this country, and this is one of the uses to which large reflectors have been put. Another English amateur astronomer, Isaac Roberts, with a 20 in. mirror pursued the subject extensively in the late 'eighties and early 'nineties. He brought out two volumes of photographs of the more important nebulae visible in these latitudes. Dr Common followed up his original design of grinding mirrors himself and made a large 5 ft. mirror and a number of smaller ones. Among these was a 30 in. mirror which he presented to the Royal Observatory, Greenwich. A few photographs of nebulae were taken with it, but the telescope was mainly employed to determine the positions of minor planets, comets, satellites of Jupiter, and incidentally the discovery of Satellite VIII. Recently it has been used for photographic magnitudes and colour.

The reflecting telescope with the mirror of 3 ft., figured by Calver, was sold in 1885 by Dr Common to Edward Crossley of Halifax, who presented it to the Lick Observatory in 1905. Prof. Keeler, who was appointed Director in 1898, altered the mounting of the equatorial, making the instrument move more easily and the control of the driving more efficient. The mirror itself, made by Calver, was of excellent figure and resolved double stars of separation 0″·5. With the Crossley reflector it was found that many thousands of nebulae exist in the sky and that most of them have a spiral structure. With this telescope the VIth and VIIth satellites of Jupiter were discovered.

Towards the end of the last century the construction of reflecting telescopes was taken up by Ritchey at the Yerkes Observatory. He figured them to a very high degree of precision, and also improved the method of supporting them so that the mirror was as nearly as possible "floated." The equatorial mounting and the driving, and provision for control and guiding, were also made suitable for long exposures. The photographs of the Andromeda Nebula and the Nebula in Cygnus taken in 1901 with a mirror of 24 ins. show the perfection of the telescope. In the same year with an exposure of 40 minutes he photographed the nebulosity around Nova Persei.

Beautiful photographs of nebulae have been taken with the 60 in. and 100 in. reflectors of the Mount Wilson Observatory and with the 72 in. reflector of the Dominion Observatory. But these telescopes have in the main been applied to other uses, not so picturesque but quite as useful and necessary for the progress of astronomy. I shall deal with these later.

Coming back again to refracting telescopes, Merz after making the 15 in. glass for Pulkovo made a number of others of somewhat similar size or rather larger. The next great advance in size was the 25 in. visual telescope made for Mr H. S.

Newall in 1868 and presented 21 years later to the Cambridge University Observatory. This was followed in 1871 by a 26 in. telescope for Washington and in 1874 by a similar telescope for the Leander McCormick Observatory, Virginia. In 1878 Sir Howard Grubb made a 27 in. telescope for Vienna. In the 'eighties the Henry Brothers made a 30·3 in. telescope for Nice and a 32·5 in. one for Meudon. Alvan Clerk made a 30 in. telescope for Vienna, and a 36 in. telescope for the Lick Observatory. In the 'nineties Sir Howard Grubb made a 28 in. visual and a 26 in. photographic refractor for Greenwich and a 24 in. photographic refractor for the Cape. In 1897 the largest refractor of all, with an aperture of 40 ins. and a focal length of 62 ft., was made for the Yerkes Observatory.

What are these large refractors used for? First let us consider the visual observations. I think the main work has been the discovery of small planets and satellites and measurements of their movements and measures of double stars. With the Washington refractor Asaph Hall discovered two very small satellites of Mars. They are very near the planet and go round very rapidly. In Gulliver's travels we are told that "the Astronomers of Laputa have discovered two lesser stars or satellites which revolve about Mars: whereof the innermost is distant from the centre of the primary exactly three of his diameters and the outermost five; the former revolves in the space of ten hours and the latter in seventy-one and a half; so that the squares of their periodical times are very nearly in the same proportion as the cubes of their distances from the centre of Mars; which evidently shows them to be governed by the same law of gravitation that influences the other heavenly bodies." So they anticipated Asaph Hall.

In 1892 Barnard with the 36 in. refractor of the Lick Observatory discovered a very faint satellite of Jupiter very close to the planet. These discoveries are great tributes to the skill of the observer and the excellence of the object glasses as the satellites are very near the very bright discs of the planets. Their utility from the astronomer's point of view is that the satellites of Mars enable him to calculate the mass of the planet and its oblateness—while in the case of Jupiter, whose mass is already known, the fifth satellite gives an excellent means of determining the oblateness. The Washington refractor had a great success before it was mounted. Alvan Clerk, Junr., was testing the glass on Sirius before it was delivered and discovered a companion to the star, of about the 10th magnitude. The irregular movement of Sirius had convinced astronomers that it had an invisible companion, but the triumphant verification was made not by an astronomer but by an optician.

These large telescopes have not been used very much in the examination of planetary detail, such as the markings on Mars, but it is from the large visual refractors—and in this Barnard with the Yerkes 40 in. holds the first place—that we have derived accurate values of the dimensions of the planets and their satellites, and of Saturn and his ring system. These include several minor planets like Vesta whose angular diameter is little more than 0″·5. The measures of the diameters of Jupiter's satellites—of the order of 1″·0—were confirmed by the interferometer measures of Hamy and Michelson.

In the domain of double star astronomy large visual refractors have been

employed with great success. Wonderful results were achieved with comparatively small instruments by Struve and Dawes, Dembowski, Burnham, and others, and there is no doubt that some observers, gifted with specially good eyesight among other qualities, can accomplish as much with a 6 in. glass as ordinary people with a 12 in. But in the main it is only with the large telescopes that double stars whose distances apart are less than 1″·0 have been continuously measured. The minimum distance at which a double star is distinctly seen as two separate stars is reached when the central disc of the companion falls on the first dark ring of the primary. Taking the wave length of the light as 5500 A.U., this gives for a 36 in. telescope an angular distance 0″·14, for a 28 in. 0″·18, for a 12 in. 0″·42. But elongated images are seen with smaller separations. Aitken states that with the 12 in. telescope many stars were discovered to be double stars, whose distances were afterwards found with the 36 in. to be between 0″·20 and 0″·25. But he gives it as his deliberate opinion that under average good observing conditions the separation of pairs measured should be about double the theoretical limit. For the stars nearer than this, the best observing conditions are required. I have taken from Aitken's book the following table:

	No. of stars Total	No. of stars $<1''{\cdot}0$	No. of stars $1''{\cdot}0-2''{\cdot}0$
Herschel	812	12	24
W. Struve	2640	91	314
O. Struve	547	154	63
Burnham	1260	385	305
Hussey	1327	674	310
Aitken	2900	1502	657

The greatest importance of double star observations lies in the fact that double stars are our source of information of the masses of stars. The following table gives the masses of a number; the remarkable feature is the small range. This is verified

Star	Luminosity ⊙ = 1	Mass ⊙ = 1	Star	Luminosity ⊙ = 1	Mass ⊙ = 1
Sirius	4·8	3·3	ζ Herculis	9·1	1·7
o^2 Eridani	·009	0·6	η Cor. Bor.	2·5	1·9
δ Equilei	2·8	2·0	ξ Urs. Maj.	·85	0·8
Procyon	4·0	1·5	α Centauri	2·1	2·0
ε Hydrae	83	3·3	70 Ophiuchi	1·3	2·6
η Cassiopeiae	1·4	0·9	Krüger 60	·0044	0·5
Capella	190	8·2	a^3 Herculis	·014	1·0
85 Pegasi	1·7	2·6			

by statistical examination of a large number of stars and is of great importance in theoretical discussions of the development and evolutionary history of stars. As is natural, the class of stars whose angular separation is small contains the largest proportion of those which are fairly near to one another and which are therefore

moving quickly. Thus it is to the large visual telescopes that we are indebted for most of our knowledge of the masses of stars.

The next use of large telescopes to which I wish to draw your attention is the determination of the velocity in the line of sight by measurement of the displacement of the lines in its spectrum. Huggins attempted this with a comparatively small telescope and by visual methods. The attempts were continued at Greenwich. The results, we know now, are not reliable. The observations were too difficult for visual methods and small telescopes. The lines were very faint and the displacements to be measured very small. Vogel introduced photographic methods and obtained results with a probable error of about 5 kilometres a second. Keeler and Campbell, using the large 36 in. refractor of the Lick Observatory and a spectroscope designed for large dispersion and great stability, obtained results with a probable error of 1 km. a second. The combination of a large object glass to collect the light, a large spectroscope to resolve it, a sensitive plate to record it, with necessary technical skill in manipulation was required. More than this, Campbell went in for mass production, and this great telescope was used night after night either for measures of double stars or for the determination of velocities in the line of sight.

So successful was the Mills spectrograph on the 36 in. refractor at the Lick Observatory that Campbell was anxious, if possible, to obtain similar observations of the stars of the Southern Hemisphere. Thanks to the generosity of Mr D. O. Mills he was able to send an expedition to Santiago in 1903 and the observers determined the velocities of 500 stars South of declination $-30°$, and thus completed the list of the brighter stars in the whole sky.

Naturally this wealth of observational material yielded several important results. I will only summarize them very briefly. First they were used to determine the direction and velocity of the Sun's motion in space. The direction was already known from investigations of angular motions. The discussions of these linear velocities gives the Solar Motion as about 20 km. per second or four times the radius of the Earth's orbit per annum. This is interesting in itself, but more important because it furnishes a base line to determine mean distances of groups of stars from the amount of angular motion caused by the Sun's movement in space.

Again it showed how the velocities of stars varied according to their spectral type, i.e. how the average velocities of stars differed according as the stars were blue, yellow, or red.

It also showed how large a percentage of stars were spectroscopic binaries, i.e. double stars so close to one another that they cannot be seen as separate stars. The study of these stars, and particularly those which are variable stars as well, has given us our knowledge of the densities of stars—which may be less than atmospheric air or may be greater than that of water, and has revealed some stars known as Cepheid Variables which appear to be pulsating spheres of gas.

A number of other Observatories have engaged in this important work, but the only one to which I need refer is the Dominion Observatory at Victoria, British Columbia. A magnificent 72 in. reflector, the optical work by Brashear and the mechanical part by Warner and Swasey, was erected in 1918. It had a secondary

mirror of 19 ins. and was used as a Cassegrain for spectroscopic observations. By 1921 the radial velocities of 594 stars had been determined from the mean of five or six plates for each star. These stars range about 6·0 mag., and even with the light-grasping power of the great mirror, probably an average exposure of somewhere near half an hour was required. In addition many spectroscopic binaries were found and these were observed further. A catalogue of 100 binaries has also been published. This is a splendid piece of work and we shall agree that the Director, Dr Plaskett, and his staff deserve to have such a fine telescope.

Within the last 15 or 20 years many large telescopes have been used in the determination of stellar parallax. Here it is not light-grasping power but large scale, sharp measurable images, and a constancy of adjustment in the glass which is required, as photographs taken months apart have to be compared. At the beginning of the century, I suppose the parallaxes of 80 stars were known. Now the number must be at least 2000. A number of observatories, about six in America and Greenwich in England, are co-operating in this work, the Directors of the Observatories forming a Committee with Prof. Schlesinger as Chairman.

As a result we are now in possession of facts about the absolute luminosity of stars which have largely affected our ideas of stellar evolution. This brings me to another large telescope, the 60 in. reflector of the Mt Wilson Observatory. Like the British Columbia telescope, it was used among other things to determine velocities in the line of sight. But another use was afterwards made of the spectra. Here I must state that stellar spectra are arranged in one continuous series and the main differences are differences of temperature, not of chemical constitution. But some minor differences were discovered by Adams and Kohlschütter. By comparing the spectra of two stars—alike in other respects—it appeared that there were differences between the spectra of a very luminous but distant star and a near but less luminous star of the same apparent magnitude. This is an empirical relationship found by comparing the spectra of stars whose distances are known. It can be applied to stars whose distances are not known and thus from the intensity of certain lines in the spectrum the intrinsic luminosity of a star can be inferred. The intrinsic luminosity means the brightness the star would have at a certain specified distance, say a million times that of the Sun. Comparing this with the apparent luminosity of the star we have a measure of its distance. This has been applied to 3000 stars and the results agree very well with the distances found by trigonometrical methods.

This is only one of the researches carried out by the 60 in. reflector and by the still larger 100 in. one. They have been applied to fathom the extent of the stellar universe as far as we can. Stars have been photographed fainter than the 20th magnitude. Mr Seares has with much skill and labour obtained accurate determinations of magnitude of a sequence of stars round the North Pole from Polaris downwards to below magnitude 20. He has also found what are called photo-visual standards nearly as far. His colleague, Mr Shapley, has photographed many distant clusters, and from variations in the light of some of the stars as indicated by the differences of photographic and photo-visual magnitudes, and in other ways,

has been able to extract such information as to enable him to form an idea of the intrinsic luminosity or absolute magnitude of certain stars in the clusters. Comparing with the apparent magnitude on Mr Seares' scale he is able to estimate the distances of many of these bodies. Mr van Maanen has photographed a number of spiral nebulae. These bodies are found to have very great velocities in the line of sight, and also different parts have different velocities. This led Mr van Maanen to investigate the possibility of detecting angular motions. By comparing photographs taken with the 100 in. reflector a few years apart he found indications of motion along the arms of the spirals. The great focal length of the telescope made the detection of these very small movements possible.

The latest use to which the 100 in. reflector has been put is the measurement of the angular diameter of stars. Prof. Michelson, assisted by Mr Anderson and Mr Pease, succeeded by an interference method in measuring the diameter of Betelgeux, and since then those of Aldebaran and one or two other stars.

A steel girder 20 ft. long was mounted on the telescope tube. This carried two plane mirrors whose distance was adjustable; they reflected the two parallel beams which reached them from the star to two other plane mirrors which reflected the light on to the large 100 in. mirror. The beams were brought together in the Cassegrain telescope and from the interference fringes the angular diameter of the star was derived. For this very delicate and difficult observation the optical power of the 100 in. telescope was not required, but advantage was taken of its stable frame and excellent equatorial mounting. For the present this is the last achievement of large telescopes, and is a land-mark in astronomical history. We may say that in the last 25 years, thanks to the optical and mechanical perfection of their large telescopes, astronomers have penetrated into the structure of the stellar universe with a success which may be compared with that attained by physicists in penetrating the structure of the atom.

The illustrations are specimens of the work of Common, Roberts, Ritchey, the Lick Observatory, the Mt Wilson Observatory, and the Victoria Observatory.

DESCRIPTION OF FIGURES IN PLATE

Fig. 1. Orion Nebula (Common).
Fig. 2. Great Nebula in Andromeda (Roberts).
Fig. 3. Nebula in Andromeda (central portion) (Ritchey).
Fig. 4. Spiral Nebula M 33 Trianguli (Lick Observatory)
Fig. 5. Nebula S. of ζ Orionis (Mt Wilson Observatory).
Fig. 6. Cluster M 13 Herculis (Victoria Observatory).

Fig. 1.

Fig. 2.

Fig. 3.

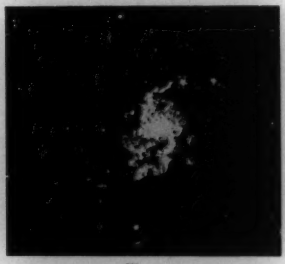


Fig. 4.

Fig. 5.

Fig. 6

THE BIRTH OF KINEMATOGRAPHY, AND ITS ANTECEDENTS

By W. DAY

A LECTURE on the above subject was delivered on 25th January, 1923. Some of the principal writings and inventions referred to are given in the following chronological tables*:

Science of Optics and Early Portrayals of Life Motion.

Chinese shadow shows, using buffalo hide figures on parchment screen	5000 B.C.
Glass formed at Sidon by the Phoenicians	*ca.* 400
First lens formed by glass globe filled with water—Hero of Alexandria	
Persistence of vision mentioned in writings of Lucretius	65
Persistence of vision mentioned in writings of Claudius Ptolemy	130 A.D.
Alhazen's writings on optics	1100
Bacon's writings mention many items of applied optics	1260
Many remarkable optical applications mentioned by Leonardo da Vinci, born in	1452
Maurolycus' writings in the early part of the 16th century	
Girolamo gives many interesting facts in his book written about	1550
Giovanni Battista Porta wrote his book *Magica naturalis*	1558
Dr Dee's work on optics	1570
Thomas Digges' work on optics	1571
Francis Bacon's work on optics	1626
Descartes' work on lens grinding	1638
Galileo, Huygens, Manzini, James Hodgson, Smith, and Sir David Brewster all propounded important theories in their books on optics.	

The Optical Lantern.

The ancient Priests and Magi used optical lanterns and lenses in Temples at Tyre and throughout Egypt, Greece, and the Roman Empire	
Athanasius Kircher and Walgenstenius invented the optical lantern in its present form at the Jesuit College, Rome	1640
Zahn's *Artificialus telediopticus*—the first published work after Kircher's book *Ars magna lucis et umbrae* to give an exhaustive account and illustrations of the optical lantern	1685
Professor Child invented the Bi-unial Lantern and Phantasmagoria	1801
The Polytechnic gave early lantern displays	1838
The Coliseum, Regent's Park, gave early lantern displays	1850

The Camera Obscura, the Camera, and Photography.

Camera obscura first suggested by Friar Bacon	1260
Leonardo da Vinci first gave illustrations explaining theory and application of camera obscura towards the close of the 15th century	
Camera obscura written of and fully described by Giovanni Battista Porta in his book	1558
Camera obscura fitted with lens first mentioned by Daniel Barbaro	1568

* Copyright by W. Day.

Alchemists in Middle Ages noted change of white chloride of silver to black chloride
Germany wrongly claims invention of photography for Dr John Hermann Schultze 1727
First actual photography on paper invented by Thomas Wedgewood . . 1792
Sir Humphry Davy assisted Wedgewood and introduced him to the Royal Society
Dr Wollaston and Mr Ritter, early experimenters in science of photography
Nicéphore de Niepce, the originator of the Daguerrotype 1814–27
Daguerre perfected and produced Niepce's invention 1829
William Henry Fox-Talbot invented the Talbot-type process . . . 1833
Professor Faraday and Sir John Herschel both carried out researches in the science of photography and read papers before the Royal Society . . 1839
Rev. J. B. Reade invented the ferro-prussiate process
Other clever inventors in the science of photography include Mons. Hippolyte Bayard, Scott Archer, Sir William Crookes, John Spiller, Sayce and Bolton, Dr R. L. Maddox, and Clerk-Maxwell

Light and its Application to Projection.

Sunlight reflected by the aid of mirrors and used to project forms of images in the ancient Temples of Egypt and Greece
Candle and oil lamps were both used by the ancients.
Huygens' undulatory theory of light
Sir Isaac Newton's corpuscular theory of light 1672
Professor Gravesend first produced four wick oil lamps for use in lanterns
Argand invented his atmospheric oil lamp 1789
Argand invented his atmospheric gas lamp 1808
Bude light invented 1810
Lieut. Drummond invented the oxy-calcium light 1826

Electricity.

First records of electricity by Thales of Miletus . . . . . 600 B.C.
Sir Isaac Newton mentions knowledge of electricity . . . . . 1675 A.D.
Sir Charles Newton
Count Alessandro Volta 1745–1827
André Marie Ampère 1775–1836
Professor Faraday
Sir Humphry Davy 1801
Soleil Dubosq clockwork arc lamp
The dynamo first suggested by Arago 1824
John Browning's arc lamp 1858
Other clever inventors of electrical generating apparatus include Pixie and Ritchie, Clarke, Nollett, Siemens, Wills, Ladd, and Gramme

Films as applied to Photography.

Celluloid—a mixture of nitro-cellulose and camphor—invented by Mr Alexander Parker of Birmingham 1675
Celluloid first used as a flexible support for a photographic negative by Mr Hyatt of Newark, New Jersey 1867

Celluloid first manufactured commercially for photographic purposes by John Carbutt of Philadelphia 1884
Celluloid film in ribbon form for use in kinematography first patented by Rev. Hannibal Goodwin, an American clergyman 1887
Later patented by Mr Reichenback for the Eastman Co.

Kinematography and Inventions leading thereto.

Theory of persistence of vision applied by Dr Roget to moving objects . 1824
Thaumatrope invented by Sir John Herschel 1826
Phenakistoscope or Fantoscope invented by Dr Plateau of Ghent . . 1827
Stroboscope invented by Dr Stampfner of Vienna 1827
Professor Faraday produced Faraday's Wheel 1831
Dr Horner of Bristol invented the Daedaleum 1834
Fox-Talbot claimed photographs in rapid sequence 1840
Perret and Lacroix applied front shutter to Fantoscope 1850
Franz Uchatius, an Austrian Lieutenant, first projected Fantoscope . . 1851
Omnius and Martin photographed the movements of the beats of an animal's heart 1865
J. A. Rudge of Bath showed moving photographs in the lantern . . . 1866
Beale of Greenwich invented the Choreutoscope 1866
Linnett invented the Kineograph, the first book of moving pictures . . 1868
Thomas Ross, Junr., invented his Wheel of Life 1869
Mr Trevor patented a process for taking a series of radial photographs on a glass disc 1869
Mr Heyl of Philadelphia invented the Phasmatrope 1870
Professor Marey of Paris commenced experimenting with motion photography 1871
Eduard Muybridge invented the Zoopraxiscope and commenced experiments 1872
Wordsworth Donnisthorpe patented a lantern plate process 1876
Reynaud of Paris produced his Praxinoscope 1877
Friese-Greene first experimented with moving pictures on glass . . . 1885
Friese-Greene invented commercial kinematography 1889
Thomas Alva Edison invented the Kinetoscope 1891
Cecil Hepworth commenced experiments with kinematography . . . 1894
R. W. Paul first manufactured the Kinetoscope in England 1894
Birt Acres took first motion pictures for R. W. Paul 1894
Mons. Lumière first perfected and produced his Cinematographé, July, 1895
First public display of animated pictures given by Mons. Trewey for Mons. Lumière at the Royal Polytechnic Institute, Regent Street, October, 1895, and later at the Empire Music Hall on 20th February, 1896
R. W. Paul first showed moving pictures at Earl's Court, 1895, and later at the Alhambra Music Hall in March, 1896

SPECTACLES AND SPECTACLE CONSTRUCTION

At a meeting of the Society held on 30th November, 1922, the following papers, dealing with some of the problems connected with spectacles and spectacle construction, were read.

An Exhibition of Instruments and Appliances connected with the Spectacle-making Industry was held on the same day. For a list of the firms represented and their exhibits, see *The Optician*, 8th and 15th December, 1922, pp. 260, 270.

SOME RECENT DEVELOPMENTS IN SPECTACLE LENSES

By W. A. DIXEY

After a period of comparative detachment from the optical trade, I find the following among recent developments to be open to comment:

(*a*) The use of a filtering glass which absorbs rays of higher frequency, and

(*b*) Some new developments in the provision of so-called periscopic lenses.

To take the latter first, the calculation for the best form of lens has furnished a subject for controversy dating from the days of Wollaston and Wharton Jones, down through Ostwald, Percival and others to the present day. Different mathematicians have given us different results, and this is not surprising when we remember that any formula on which calculations are based must contain constants which may be variously estimated. I can enumerate six limiting conditions which preclude an exact result.

(1) The distance of the centre of rotation from the front focal plane of the eye is a controlling factor; it varies with the size of the eye, and the human eye varies in individuals just as human stature does. You have to take an estimated average, which you may or may not adjust to the degree of ametropia.

(2) The range of direction of the visual lines is variable. You may take 40°, 50°, or 60°, and your results will vary accordingly.

(3) In an asymmetrical lens, e.g. sph. + 1·00, cyl. + 4·00, you have to choose between a curve of 1 *D* and a curve of 5 *D*. Whichever you select, the lens will be 4 dioptres out in the opposite direction, and if you take the mean you are 2 dioptres out at both axes.

(4) The accuracy of your calculated correction is dependent on the position of the spectacle lens relative to the front focal plane. This is not the same as (1). The conformation of the patient's face may render the assumed position of the spectacle lens impossible. A further (so-called vertex) correction is then necessary which will modify the curves of the lens.

(5) Variety of index and

(6) The limits of graduation are two minor considerations which affect the problem very slightly but still interfere with that mathematical precision which a "perfect" lens should connote.

From these considerations I want you to infer that perfection is impossible. But that is not to say that we are not to aim at a reasonable approximation; and what I propose to do in this paper is to examine what aberrations it is desirable and possible to correct, to give some idea of how by modifying the curves of our lenses we may effect an approximate correction, and to show how far this correction may be attained with the means at our disposal.

There are three classes of aberration which have been considered as applicable to spectacle lenses.

(1) *Spherical aberration.* This was effectively dealt with twenty years ago, I think, by Dr Drysdale, and the record of his demonstration will be found in the early *Transactions* of this Society. For the benefit of junior members I may recall the demonstration. You take a + 20 *D* lens, place it in the worst position, allow a generous pupil aperture and calculate the diameter of the confusion circle; you will find it less than the diameter of the sectional area of the retinal cones. Thus spherical aberration is ruled out.

(2) *Aplanatism and distortion.* These I similarly rule out—I think you will all agree; I will not therefore elaborate my reasons, but will be pleased to explain if I am questioned afterwards.

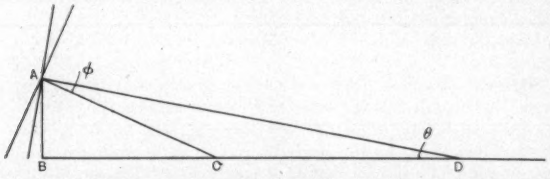
(3) *Radial astigmatism.* This is the one thing that matters, and that for two reasons: (*a*) for definition, which is not so important because it is only very slightly affected, but especially (*b*) for prophylactic reasons, because we are told, and it is general practice to accept, that even a slight degree of uncorrected astigmatism leads to binocular strain, nervous disorganisation, and various possible pathological sequelae.

Let us now consider how radial astigmatism may be corrected by modifying the form of the lens. As the eye rotates round its centre, the line of sight cuts at different angles a flat glass placed as a spectacle glass in the front focal plane of the eye system. The condition for the line of sight to cut the glass normally in every position is that the two surfaces of the glass should be sections of spheres concentric with the centre of rotation. If we take 26 mm. as the distance of the front focal plane from the centre of rotation, this gives us a 40 dioptre curve, or the curve which is associated in our minds with a 20 *D* lens—an obviously inconvenient degree of curvature to deal with. The problem therefore arises, how far we may reduce this curve without creating an effective amount of radial astigmatism. We must define our range of rotation, and if we take 50°, that gives us an obliquity of 25° for the extreme marginal visual line. In a flat (equi-bi-spherical) glass we find the cylindrical effect at an angle of 25° to be (approx.):

0·06 for 0·25 *D*
0·12 ,, 0·50 ,,
0·25 ,, 1·00 ,,
0·75 ,, 3·00 ,,
1·50 ,, 6·00 ,, and so on.

Clearly with ordinary bi-spherical lenses a considerable degree of astigmatism is engendered. This is with a mean curvature in relation to the centre of rotation which we may represent as zero. It is clear that as you leave the zero curve and approach 20 *D* you modify the angle at which the visual line cuts the lens, and so reduce the amount of radial astigmatism.

A simple calculation enables us to find the angle at which our 25° marginal line will cut the tangents to the several curves intermediate between zero and 20 *D*.



In the accompanying figure let $\angle ACB = 25°$, $BC = 26$ mm., and $BD = x$ = radius of curvature of lens intermediate between 0 and 20 *D*. Then

$$\tan \theta = \frac{AB}{x} = \frac{26 \tan 25°}{x} = \cdot 145$$

if we put $x = 83{\cdot}5$, the radius of curvature for a 6·00 *D* surface. Hence $\theta = 9°$ and $\phi = 16°$. The line will therefore cut the curve at an angle of 74°. Similarly, the angles for 3·00 *D* and 9·00 *D* curves are 70° and 78° respectively.

To show the cylindrical effect of visual lines 25° from the normal, traversing curves of 3, 6, and 9 dioptres, upon powers of different strength we have the following approximate values:

Power of Lens	Base 3·00 *D* Angle 70°	Base 6·00 *D* Angle 74°	Base 9·00 *D* Angle 78°
1·00	0·13	0·07	0·04
2·00	0·26	0·14	0·09
3·00	0·40	0·21	0·13
4·00	—	0·28	0·17
5·00	—	—	0·22
6·00	—	—	0·27

I have chosen to tabulate these three powers, because most of our toric tools in England are made to a 6 *D* base; 3 *D* and 9 *D* base tools are also available, though they are not in such general use; and I am interested to examine how far we can utilise our present plant, without having either to enlarge it or to resort to foreign productions.

By reference to the table you may infer that with tools that give you a choice of 3, 6, or 9 *D* convex or concave toric curves you can obtain a periscopic form of lens within the limits of + 8·00 and − 8·00 *D* in which the radial astigmatism is negligible.

This range covers perhaps 90 per cent. in ordinary practice, and of the remaining 10 per cent. a large proportion would be sphericals, for adjusting which our tools afford a wide scope.

I have here an exhibit of four specimens of glass, whose professed quality is to absorb ultra-violet rays. The glasses are described as Crookes A, Crookes A_2, Filtray, and Vitrex. As regards their filtering quality all are effective, the Crookes A and the Crookes A_2 rather more so than the others. Filtray glass (of French origin) has an index of 1·529, rather high for our English tools; the Vitrex glass is usable as regards index (1·523) but one of its merits, its pure whiteness, might prove a drawback to its use as a spectacle lens. On the whole there is no reason to look for a better material for the purpose than that which is afforded by the Crookes glass, the product of a world-celebrated English foundry, working to the formula of an equally celebrated English physicist.

DISCUSSION

Mr H. S. Ryland: There is apparently no evidence to show that any given part of the spectrum is, in the quantities usually met with, injurious to the human eye. It is probable that as people spend more time in artificial or poor light some intolerance to light will exist. Under these circumstances the cutting off of parts of the spectrum by Crookes' glass may be of benefit. In many cases the chlorophyll tints are more appreciated than Crookes' glasses.

STANDARDS OF ACCURACY FOR OPHTHALMIC PRESCRIPTIONS

By O. P. RAPHAEL

As a manufacturing optician I wish to discuss the present trend of affairs as they refer to accuracy in ophthalmic prescriptions. I want to formulate certain problems, which, by the way, I shall make no attempt to solve, and I hope to indicate certain lines upon which authorities might proceed to ensure that opticians work to a standard of accuracy which shall be the point where a greater accuracy ceases to be of value to the lens-wearing public. In some cases it may be found that the accuracy demanded should be increased, but I am sure in others accuracy is not being considered side by side with the practical optical effect involved.

Any discussions of standards in ophthalmic work should be prefaced by a reference to the committee recently formed by the Wholesale Manufacturing Opticians and the Institute of Ophthalmic Opticians under the chairmanship of Mr Lionel Laurence, which, working in harmony with a similar committee in America, is to tackle this very problem of standards. But the committee's intention is very wide—in fact it means to embrace every phase of ophthalmic work, not the least important being nomenclature. But just as the League of Nations can only be truly realised by the interest shown in it by the Nations themselves, so this

committee can only succeed in its task if the industry keeps familiar with the problems to be faced and so can understand in the future the results that will be arrived at.

Manufacturing opticians see thousands of pounds frittered away through capricious standards of accuracy of individual retail opticians, which have no scientific justification. If, on the other hand, higher standards are really of practical benefit, the manufacturer will set himself the task of attaining them with pleasure and satisfaction once the whole matter is placed on a proper footing.

Let us take the case of spherical lenses. If the effective power differs from the neutralising power by more than the limit of error for rejection, then a state of absurdity exists. But to determine the matter with nicety and establish a satisfactory standard of accuracy a multitude of factors have to be taken into account, for instance, whether one is dealing with positive or negative lenses—whether neutralisation is effected with light incident on or emergent from the ocular surface of the lens—the lens thickness—the refractive index—the distance the lens is worn before the eye—the lens form, and so on. Then, of course, important physiological considerations arise from the sight testing side in determining when the theoretical accuracy ceases to be of practical value. Assuming that the line of valuable accuracy could be established, should the limit of admissible error be expressed in dioptres, in percentage of total power, or quite different terms? Should neutralisation be the means of testing or some other method, say, the measurement of the back focal length? These are all little problems attendant on the greater one of standardisation, and worthy of careful consideration. In cases of astigmatism—apart from the error in power such as may be admissible—what accuracy should there be in placing the cylinder? Not surely the arbitrary "so many degrees" which satisfies many opticians, because, of course, the astigmatic effect increases with the power of the cylinder for the same degree of inaccuracy. And how is this finding affected—if at all—by the combination of a sphere with the cylinder both con- and contra-generic. In the matter of cylinders, is it not reasonable to ask how far the type of mounting affects the practical value of fine accuracy?

The inter-pupillary distance in prescriptions gives rise to fresh enquiries. How far is accuracy required for geometrical exactitude, and how far for the purely optical effect? A wholesale optician told me the other day that a pair of Kryptok bifocals were rejected by one of his influential clients because the pupillary distance was 60 mm. instead of 61 mm. Now a geometrical error of $\frac{1}{2}$ mm. in each eye is simply inappreciable and I have grave doubts that a prismatic effect of $1/10\Delta$ (the prescription being about $+2\,D$ sph.) in each eye could be considered to exist. The optician could never have considered what the prismatic power in the segment might be, if indeed the cause of rejection was the inter-pupillary measurement in the distance portion. And so with weak positive and negative sphero-cylinders, which are notoriously difficult to manufacture with perfect centration, rejections are made for an optical decentration which in terms of prismatic power appear ridiculous. The same point arises with prismatic lenses themselves. Although one knows that the bridge measurements in Devonshire will consistently differ from those in Yorkshire, I for one am a little doubtful that the people of a certain seaside

town should all need the smallest prisms combined with practically every lens they wear, whereas such combinations are not required elsewhere. Is it that prescribing opticians and oculists in other towns are not alive to their patients' needs, or is it that these prisms are—let it be whispered—of more than doubtful value? And in either case, to what extent may the prisms be weak or strong? If, after research it is established that prisms below a certain power—either having or not having relation to the type and power of lens with which they may be combined—fail to have any ophthalmic significance, then surely lenses, of which the prismatic errors or incorrect decentration are equivalent to that same insignificant prismatic power, may be considered to be of the highest necessary accuracy as far as the prisms or centration are concerned. And with bifocal lenses, to mention but one point, what allowances, if any, should be made for the fact that the reading portions, always being used at an angle as it were, produce a sphero-cylindrical effect?

Now, in any discussion upon accuracy, as determined by some particular test, one must examine the means and method of the test itself. Thus we are bound to give some thought to the common means of prescription testing—neutralisation. This method is only really satisfactory when dealing with thin lenses and in flat form. As far as thickness is concerned this has been satisfactorily overcome by our agreeing to deceive ourselves by calling the powers of positive lenses those of the negative lenses which neutralise them.

Flat-form lenses enable light emergent from the ocular surface (as when the lens is worn before the eye) to be used for neutralisation, but in dealing with curved lenses, owing to the fact that emergent light at the ocular surface cannot be used for the test without having a lens of air between the ocular surface and the testing lens, incident light has to be used.

Dr C. Sheard* gives a simple formula for calculating the *approximate* neutralising power of a lens, namely,

$$D_1 + D_2 + \frac{t \times D_2^2}{\mu} + \ldots$$

where D_1 is the power of the front surface in dioptres, D_2 the power of the ocular surface in dioptres and t the thickness of the lens in metres. Since $D_1 + D_2$ merely expresses the nominal power of the lens the whole importance must be in the third term. Now in the third term is quoted only the ocular of the two surfaces, and thus it will be realised that there is going to be an appreciable difference in the results if neutralisation is from one side or the other. Therefore the findings from neutralising curved form lenses must necessarily be inexact.

But, possibly, the most important of all matters relating to accuracy in manufacturing prescriptions remains to be stated. It is that the form of lens has an influence upon the *effective* power of all combinations when in front of the eye. Quoting again from Dr Sheard we have this formula for calculating the approximate effective powers of lenses:

$$D_1 + D_2 + \frac{t \times D_1^2}{\mu} + \ldots$$

* *Amer. Journ. Ophth. Opt.* 3 (Oct. 1922) 345.

where the symbols have the same significance. Here it will be realised that the importance lies with the thickness and the outside curve of the lens. The reduced thickness possible with negative lenses and the lesser curve on the outside naturally mean that the effective power in a meniscus form negative lens will not differ from the nominal power to the same extent as will be the case with a positive lens. This effective power will vary, as the formula makes clear, according to the base curve used in manufacture.

Now in a meniscus form lens the neutralising power, although not necessarily the same as the nominal power, will not be as different from that nominal power as will be the effective power. What then is the use of checking to a fine degree of accuracy by neutralisation a lens made in meniscus form when prescribed in nominal powers?

The solution of the difficulties I have raised I will not attempt to give, but it must make us all reflect upon the necessity of the oculist or optician prescribing not only the powers of lenses, but the form to which these powers are to be understood to apply. Surely it will be agreed that some standardisation here is desired.

One might reasonably ask whether the optician's future lies in calculating formulae in the back parlour. Probably not, because methods other than neutralisation may be adopted as the recognised test for ophthalmic prescriptions. The back focal length, that is to say the focus measured from the ocular surface of the lens, gives the effectivity of that lens, and seems to be the ideal method of measurement for modern use. The instrument I have here measures the back focal length of spheres, cylinders, sphero-cylinders, and registers decentrations. My firm has had a number of them in use for prescription manufacturing so as to give the effective powers to which I have referred, and it is heartbreaking to find a lens perfect in effectivity which has, at considerable expense, to be remade incorrectly, in order to give the retail optician the neutralisation which he seeks.

DISCUSSION

Mr H. S. Ryland: It is always good to strive for accuracy. On the other hand it is useless for lens manufacturers or prescription houses to work to a degree of accuracy far beyond that obtainable by the refractionist (or optician). The intervals between the spherical and cylindrical lenses, and their position in the trial frame, have an equivalent power which differs from that of the single spectacle lens by an amount greater than the differences between lenses of the various usual forms.

Mr Raphael: Mr Ryland's point is a valuable one, and, if I may say so, an extension of my own argument. In establishing standards of accuracy in the manufacture of ophthalmic prescriptions one's results should be made to run parallel with the practicable accuracy of the sight-testing itself and the latter is dependent upon the means of sight-testing available. I have already expressed my doubt that this consideration is given its full weight.

PARAXIAL ACTIONS OF OPHTHALMIC LENSES

By W. SWAINE, B.Sc.

ABSTRACT. The object of this paper is to draw attention to the cumulative effect of the various approximations used in refraction work.

Modern ophthalmic practice has evolved by experience in the direction of greatest practical convenience with regard to standardised units and the methods of measuring both refractive errors and spectacle lenses. With the increased knowledge of physiological optics, however, there are certain practices untenable. Briefly present-day practice is the following:

(1) Lenses are designated with powers in dioptres, i.e. with the reciprocal values of their focal lengths expressed in metres, a positive sign indicating converging power*.

(2) The Optical Society's Committee for the standardisation of trial case lenses† decided

(*a*) To use symmetrical lenses of standard or minimum central thickness.

(*b*) To mark negative lenses with their 'true' powers, i.e. with the reciprocals of their focal lengths measured from the principal points.

(*c*) To number positive lenses with 'nominal' powers, i.e. with a number equal and opposite to the true power of the neutralising negative.

(3) The measurement of an ametropic error consists in choosing that trial lens (placed so as just to clear the eyelashes) whose focal point coincides with the far point of the defective eye. The degree of the error is called the spectacle refraction of the eye and is expressed as the nominal power of the correcting lens.

(4) The subsequent spectacle lens for use in distance vision is placed in a like position in front of the eye, the intention of the process to be one of direct substitution. The correction of central astigmatism may be regarded almost as a particular case of the correction of ametropia, but the cylindrical lenses of the trial case must of necessity be separated by the cell separation of the trial frame, whilst the ensuing spectacle lens is a unit.

(5) It is generally assumed that the thickness of ophthalmic lenses, cell separations, etc., may be ignored so that transpositions of lenses or of prescriptions are only regarded as examples of simple addition of power.

(6) An erroneous idea is common—that all lenses which neutralise the same lens are equivalent in their optical action at the eye. This error has already been detected and corrective tables drawn up‡. The existence of these tables is not generally known, their application can only be regarded as a temporary expedient, and their necessity constitutes an apparent weakness of the neutralising principle.

(7) Considerable care is exercised in obtaining an accurate estimation of the static refraction of the eye, whilst a rigorous near vision test awaits discovery. There

* F. Monoyer, *Ann. d'Ocul.* 68 (1872) 101.

† *Trans. Opt. Soc.* 9 (1908) 138.

‡ Max Poser, *Optician*, Sept. 4, 1914.

are several optical considerations when lenses are used in near work which are of interest in this connection.

(8) The refractionist sends a prescription to the dispensing optician who sends it to the manufacturing optician. The latter may have procured the required lens from an importer, when the glass was manufactured originally in this country.

Effectivity.

A process of frequent occurrence in ophthalmic optics is the referring of a power to some neighbouring origin distant a few millimetres or centimetres away. This change of relative power with change of origin is generally described as effectivity modification. A power of 5·0 dioptres signifies that the focal point is 20 cm. from the prescribed origin of measurement. If a new origin 5 cm. further away from the focal point be chosen, the effective focal length is 25 cm. or the effective power is $100/25 = 4{\cdot}0\ D$. The writer finds that the use of a specially constructed reciprocal slide-rule saves time. Good quality squared paper with fine millimetre squares (20 cm. × 30 cm.) was first numbered the long way from the top left hand corner at each centimetre mark 650 to 620. The centimetre line below was then marked 620 to 590 and so to the right hand bottom corner with 20. Using Barlow's tables of reciprocals graded marks were made thus: 1·55 at 645·2, 1·56 at 641·0 and so on. The graded reciprocal marks thus constitute a dioptre scale when the equidistant points represent corresponding millimetres of focal length.

A strip of paper (millimetre squares) 30 cm. long and any width desired, to be used as a cursor, was marked 0 to 30, 30 to 60, and so on if required. On the same strip a backward reading scale was also marked. By placing the zero of the cursor opposite any power the effectivity modification for any reasonable distance positive or negative is obtained by direct inspection. By mentally displacing the decimal points, the scale of the slide-rule may be conveniently altered ten times or one-tenth, thus increasing the range of usefulness and degree of accuracy.

As an example of its use—convert the true powers of trial negative lenses to vertex power. These lenses have a constant central thickness of 1 mm. and a constant distance of principal point from the vertex ·33 mm. Using the backward reading cursor for negative powers (the new origin is more removed from the focal point) we may obtain the following table:

Table I. *Vertex Powers of Trial Negatives.*

True Power	0	−5·00	−10·00	−15·00	−20·00	−25·00	−30·00
Vertex Power	0	−4·99	− 9·97	−14·92	−19·88	−24·79	−29·71
Difference	0	·01	·03	·08	·12	·21	·29

To obtain the figures for − 25·00 and − 30·00 the 2·5 or 3·0 dioptre marks may be used whilst the cursor's scale is multiplied by 10.

*Vertex Power in Relation to Neutralisation**.

The condition of neutralisation is coincidence of adjacent focal points when the vertices of the neutralising lenses are in contact. This is equivalent to the statement that the vertex powers of these lenses are equal and opposite (i.e. their powers referred to the contact vertices). Table I then gives the numerical value of the vertex powers of the trial positives and they will in consequence be equal to the nominal powers—the differences are almost negligible in practice and within the limits of error suggested by the Standards Committee. Incidentally it may be observed that the same committee tabulates the principal or true powers of the standard positives. This numbering differs from the nominal numbering by quantities greater than the permissible error.

Vertex Power in Relation to Spectacle Refraction†.

The separation of the tips of the eyelashes of an ametropic eye from the far point of the same is a constant quantity for that eye and under the conditions of sight-testing is numerically equal to the reciprocal of the back (inner) vertex power of the distance correcting lens. Any directly substituted spectacle lens should have the same back vertex power. For symmetrical lenses the back and front vertex powers are equal and this is probably the chief reason that the standard trial lenses were made in equi-form (this together with the convenience of rapid manipulation during a test).

Unsymmetrical spectacle lenses are usually neutralised by placing the neutraliser in contact with the more convex surface of the lens to be measured. In relation to this lens's position in front of the eye the neutraliser so used will measure the front vertex power of the lens. Whilst the back vertex power measures the power of importance to ensure conjugate equivalence at the eye, the front vertex measures the neutralising lens as at present used‡. Since in the case of unsymmetrical lenses these two powers are not equal, it is of importance to realise the amount of difference existing.

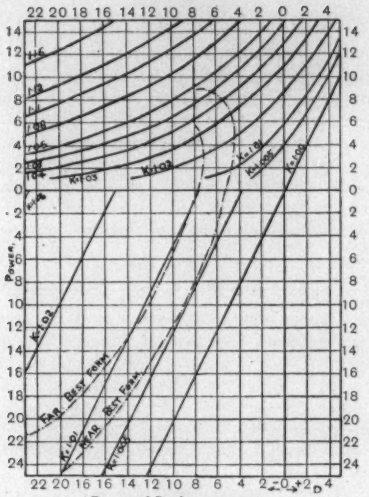
In the accompanying chart ordinates are back vertex powers whilst abscissae refer to the powers of the back surfaces. Each curve connects those forms of lenses with equal ratio of back to front vertex power. Equal back vertex power lenses were assumed to have the same central thickness—an average thickness corresponding with an average size of eye§. The greater thickness of larger diameter lenses will tend to increase the difference between the vertex powers. The curves progress by jumps of 1 per cent. For positive lenses the abscissae (in the negative direction) represent the base curves. The dotted semi-ellipses refer to the "best-form" lenses for distance or near use, as given by Mr Whitwell.

* W. Swaine, *Optician*, Oct. 8, 1920.

† O. Henker, *Z. f. Ophth.* 1914.

‡ W. Swaine, *Inst. Ophth. Opt.* Nov. 18, 1920; *Optician*, July 22, 1921, Jan. 27, 1922; A. Estelle Glancy, *Amer. Journ. Ophth. Opt.* Jan. 1921; A. Whitwell, *Optician*, Jan. 21, 1921; C. Sheard, *Amer. Journ. Ophth. Opt.* 1922.

§ W. Swaine, *Optician*, Jan. 27, 1922.



For negative lenses there is no serious difference between front and back vertex powers. For positive lenses there are limiting back vertex powers for which the difference amounts to more than a permissible percentage. Table II is taken from this chart.

Table II. *Limiting Back Vertex Powers of Positive Lenses for which front vertex power exceeds the back by certain percentages.*

Percentage Difference	Base			
	−3	−6	−8	−9
1	+3·0	+1·2	+1·0	+0·9
2	+5·5	+3·7	+2·8	+2·6
3	+8·0	+5·9	+5·0	+4·0

It follows that if an unsymmetrical positive lens neutralises a prescribed trial lens there will result an overcorrection. Suppose a + 14·0 lens is found as a result of refraction and that a lens on a − 9·0 base is prescribed. If a lens be made which neutralises a − 14·0 lens placed on its convex face, the lens will overcorrect by

11 per cent. or + 1·5 *D*. There is thus a liability of misinterpretation of a prescription between oculist, optician and manufacturer. A standard agreement should be fixed. On the continent Messrs Zeiss overcome the difficulty with an instrument for measuring vertex power. Corrective tables or charts are troublesome and past experience has proved their poor value, since lens substance should also be specified. Probably the most satisfactory solution is that adopted by Messrs Stigmat, Ltd.—a small neutralising set which can be placed at the back vertex of meniscus lenses, thus measuring back vertex power.

Vertex Relations.

Transforming the paraxial equation for refraction at a single surface

$$\frac{n'}{a'} - \frac{n}{a} = \frac{n' - n}{r} \qquad \text{.....(1)}$$

to the convenient Gullstrand convergency notation

$$A' = A + D \qquad \text{.....(2),}$$

where A is the dioptral expression for the reduced position of an object, A' that for the image, and D the reduced power of a surface (i.e. power of a lens surface as understood in ophthalmic optics), we have

$$A_1' = A_1 + D_1, \qquad A_2' = A_2 + D_2$$

where A_2 is the effective value of A_1' at the second surface

$$[A_2 = A_1'/(1 - \delta_1 A_1')].$$

The effectivity modification must be across the reduced thickness of the lens ($\delta_1 = t_1/n_2$). It immediately follows that

$$A_2' = \frac{A_1 + D_1}{1 - \delta_1 (A_1 + D_1)} + D_2 \qquad \text{.....(3)}$$

$$= \frac{A_1 (1 - \delta_1 D_2) + (D_1 + D_2 - \delta_1 D_1 D_2)}{1 - \delta_1 (A_1 + D_1)} \qquad \text{.....(3a).}$$

When $A_1 = 0$, i.e. for an infinitely distant object, $A_2' = V_{12}$ = back vertex power. Hence

$$V_{12} = \frac{D_1}{1 - \delta_1 D_1} + D_2 \qquad \text{.....(4)}$$

$$= \frac{D_1 + D_2 - \delta_1 D_1 D_2}{1 - \delta_1 D_1} = \frac{D_{12}}{1 - \delta_1 D_1} \qquad \text{.....(4a),}$$

where D_{12} is the principal or true power of the lens. Reversing the direction of the light, the front vertex power becomes

$$V_{21} = \frac{D_{12}}{1 - \delta_1 D_2} \qquad \text{.....(5)}$$

$$= \frac{D_2}{1 - \delta_1 D_2} + D_1.$$

Transpositions.

To find the vertex power of lenses, given the surface powers and thickness, equation (4) is most convenient and states the method: with the reciprocal rule modify D_1 effectively through δ_1 and add D_2. To find the combining surface, given the back vertex power, base, and thickness, rewrite equation (4)

$$D_1 = \frac{V_{12} - D_2}{1 + \delta_1 (V_{12} - D_2)}.$$

With the reciprocal rule effectively modify the vertex power algebraically less the base power through the *reduced* thickness backwards.

The usual text-book treatment is to ignore thickness. The errors which accrue in certain leading cases will be evident from Table III which has been calculated by means of the reciprocal rule.

Table III. *Combining Surfaces.*

Back Vertex Power (V_{12})	+ 5·0	+10·0	+15·0	+20·0
Thickness (t_1) in mm.	2·7	4·3	6·0	7·8
Reduced thickness ($\delta_1 = t_1/n_2$) in mm.	1·78	2·82	3·94	5·12
Base −3·0	+ 7·89 (8)	+12·52 (13)	+16·81 (18)	+20·60 (23)
−6·0	+10·78 (11)	+15·31 (16)	+19·40 (21)	+22·92 (26)
−9·0	+13·66 (14)	+18·01 (19)	+21·94 (24)	+25·28 (29)

The unit, except in the 2nd and 3rd rows, is the dioptre. The figures in brackets are the infinitely thin lens transpositions.

To reproduce the trial vertex power these curves should be reduced by the negligible quantities indicated in Table I.

Table IV shows the maximum thickness of lenses of standard forms, for which the simple transposition method may be used.

Table IV.

Back Vertex Powers (Base)			Maximum thickness for accuracy	
−9·0	−6·0	−3·0	0·06 *D*	0·12 *D*
—	—	1	5·8	12·8
—	—	2	3·5	7·5
—	0	3	2·7	5·6
—	1	4	1·8	3·6
—	2	5	1·5	3·1
0	3	6	1·1	2·1
1	4	7	·9	1·8
2	5	8	·8	1·5
3	6	9	·6	1·4

Vertex Astigmatism and Toric Transpositions.

There is no uniform practice when measuring the astigmatism of the eye. Some practitioners leave a slight fogging lens and measure the astigmatism using negative cylindrical lenses placed in a neighbouring cell of the trial frame. Others neutralise meridians, using the retinoscope with spherical lenses. Jackson's or Lockwood's crossed-cylinder methods may be used. It is universally admitted that small astigmatic errors, whether arising naturally or residual from a test, in a large majority of cases cause asthenopia.

There is a relatively greater effectivity change when a focal point is approached than when moving away. A positive cylinder placed before a lens in a trial frame will have a slightly greater increased effectivity than the reduced effectivity of a negative cylinder similarly placed. The difference will be further accentuated on passing through a thicker spectacle lens, e.g. a positive lens, owing to the change through its substance. In other words testing for astigmatism with negative lenses gives a closer approximation to the back vertex astigmatism required in the subsequent spectacle than when using positive cylinders.

Suppose, as an example, a prescription were written as tested

$$\frac{+\ 25{\cdot}0 \text{ sph.}}{+\ 2{\cdot}0 \text{ cyl.}} \quad \text{cell separation 5 mm.}$$

The actual vertex astigmatism would be + 2·38. If the resulting spectacle lens be prescribed to have a − 6·0 sph. inner curve, by the usual rules of toric transposition this lens would be described

$$\frac{+\ 31{\cdot}0 \text{ cyl.} \supset +\ 33{\cdot}0 \text{ cyl.}}{-\ 6{\cdot}0 \text{ sph.}}$$

whereas it should be written

$$\frac{+\ 25{\cdot}9 \text{ cyl.} \supset +\ 27{\cdot}5 \text{ cyl.}}{-\ 6{\cdot}0 \text{ sph.}} \quad \text{substance } 9{\cdot}6 \text{ mm.}$$

i.e. with a surface astigmatism of 1·6 *D*.

Or, again, the prescription

$$\frac{+\ 10{\cdot}0 \text{ sph.}}{+\ 4{\cdot}0 \text{ cyl.}} \quad \text{cell separation 5 mm.}$$

is usually transposed

$$\frac{+\ 18{\cdot}0 \text{ cyl.} \supset +\ 22{\cdot}0 \text{ cyl.}}{-\ 8{\cdot}0 \text{ sph.}}$$

and should read

$$\frac{+\ 17{\cdot}12 \text{ cyl.} \supset 20{\cdot}88 \text{ cyl.}}{-\ 8{\cdot}0 \text{ sph.}} \quad \text{substance } 4{\cdot}3 \text{ mm.}$$

The actual vertex astigmatism is 4·23 *D*, whilst the front surface astigmatism is 3·76 *D*.

If a prescription reads

$$\frac{+\ 10{\cdot}0 \text{ sph.}}{-\ 4{\cdot}0 \text{ cyl.}} \quad \text{cell separation 5 mm.}$$

it should be transposed

$$\frac{+\ 17{\cdot}12 \text{ cyl.} \supset 13{\cdot}44 \text{ cyl.}}{-\ 8{\cdot}0 \text{ sph.}} \quad \text{substance 4·3 mm.}$$

in which the actual vertex astigmatism is $-\ 4{\cdot}0\ D$, and front surface astigmatism $3{\cdot}68\ D$.

Alteration in Position of Spectacle Lens.*

If for any reason it be required to move a spectacle further from the eye, the new vertex power and vertex astigmatism may be obtained directly by means of the rule. Conversely the tolerance in position may be found to reproduce the trial correction to any prescribed accuracy.

Effectivity at the Eye. Principal Refractions.

Accommodation takes place at the eye and, as Donders has shown, the measure of accommodation should be the difference between the static and dynamic principal refractions of the eye†. Owing to the separation between the back vertex of a correcting lens and the first principal point of the eye there will be considerable differences between the spectacle refraction and the principal or ocular refraction. The reciprocal rule readily gives the necessary conversion and more conveniently than tables or charts, since fractional powers and separations very frequently arise.

In consequence of the forward position of the lens, then, the virtual amplitude of accommodation will differ from the actual amplitude. This action is well known although the writer has not seen a solution of the problem from the point of view of vertex or nominal power markings. Most solutions have only theoretical interest. A direct calculation using the reciprocal slide-rule occupies but little time and can be made to include all the factors involved, lens substance, and separation from the eye.

Table V. *Table of Actual Accommodations through Distance Correction.*

Distance correction nominal power	Virtual accommodation of the eye, measured from eye in dioptres									
	1	2	3	4	5	6	7	8	9	10
+10	1·43	2·84	4·24	5·64	7·04	8·44	9·84	11·22	12·57	13·89
+ 5	1·21	2·38	3·56	4·32	5·91	7·08	8·25	9·42	10·60	11·76
+ 0	1·00	2·00	3·00	4·00	5·01	6·01	7·02	8·02	9·03	10·04
− 5	0·87	1·74	2·61	3·48	4·35	5·23	6·10	7·00	7·89	8·77
−10	0·76	1·52	2·27	2·96	3·81	4·59	5·36	6·12	6·91	7·70
−15	0·67	1·33	2·02	2·67	3·36	4·03	4·72	5·42	6·10	6·84
−20	0·61	1·16	1·77	2·39	2·97	3·61	4·24	4·84	5·46	6·11

* O. Henker, *Z. f. Ophth.* 1914; W. Swaine, *Inst. Ophth. Opt.* Nov. 18, 1920.

† W. Swaine, *Optician*, Jan. 20, 1922.

Table V is calculated on this basis for average substances of standard symmetrical trial lenses and shows the magnitude of the modification when the back vertex occupies an average position of 15 mm. from the principal plane of the eye. It shows the actual amplitude of accommodation through a given distance correction for an ascertained virtual accommodation measured from the eye.

The table only shows the case when the correcting lens is at a mean position, whilst the position of the lens is the main factor operative. The near test is generally made under conditions involving the above principle and constitutes an important part of routine refraction. A special examination for astigmatism is rarely made. All factors considered, a rigorous near vision test is rarely made. The interpretation of dynamic skiametric measurements is too uncertain. Even when a rigorous test is forthcoming the subsequent spectacle lens, in order to function with conjugate equivalence, should be of the same form as the testing trial lens. The problem will not be as simple as the distance correction—namely a direct substitution of equally vertex numbered lenses. A permissible compromise must be effected. The use of "best-form" lenses is increasing and in the writer's opinion must continue to do so, as greater care is exercised in observing the points in this paper and others developed by Mr Whitwell.

It has been suggested that lenses should be re-standardised by using a principal point numbering, on the fallacious grounds that simple addition of powers would obtain and that near equivalence would be ensured. The policy is not practicable. Back vertex designations are too valuable to drop, and by neutralising at the back surface, instead of the front as at present a serious trouble is overcome. The oculist can verify the spectacle without the necessity of corrective tables and it becomes the duty of the manufacturer's designer to produce that lens. There still remains the problem of near equivalence*.

The author has calculated a series of tables giving the necessary back vertex lens for various forms of average thickness which demand specified accommodations for specified positions of a near object†. The underlying idea of these charts was to fill the vacancy of the rigorous near vision test, to obtain the necessary modification of spectacle astigmatism for near work lenses, to find that lens which will help to equalise accommodative effort in anisometropia, etc. Their use is discussed elsewhere but a point of interest arises in the question of a policy for approximating to near work equivalence. This problem *per se* is mainly a function of the central thickness of the positive lenses and form. Reducing the central thickness of the trial lenses and so approaching an equality between cardinal and vertex numbering will be in the wrong direction. If the central thickness of the trial positives be retained but their form altered to plano-convex such a step would approximate thereto. In the case of a hypermetrope of + 10·0 *D* spectacle refraction corrected 16 mm. from the eye, for that eye to accommodate three dioptres for an object 33 cm. in front of it a + 11·00 symmetrical lens is required, or alternatively a + 11·15

* E. Mayer, *Optician*, Dec. 10, 1920.

† W. Swaine, *Optician*, Jan. 20, 27, Feb. 3, Sept. 15, 1922; Letters to *Optician*, Dec. 24, 31, 1920, Dec. 9, 1921.

plano-convex or a + 11·20 deep meniscus (− 6·0 *D* base), all vertex marked. Plano-convex trial lenses thus constitute a useful compromise in the direction of securing near equivalence, the plane surface to be considered the back surface from which the back vertex power will be measured*. Other advantages arise: (1) the back surface being plane there is no alteration of position of back vertex with respect to the lens rims and trial frame, so that this position is more definitely located; (2) the bending approaches best form with the attendant advantages; (3) the front vertex power is a principal point power.

The writer understands that a plano-trial case was introduced some time ago by Messrs Gowlland, but does not know why it was withdrawn.

DISCUSSION

Mr H. S. Ryland: Under present conditions the tables given (also the machine described by Mr Raphael) will not help the optician greatly. Before an exact reproduction of the optician's trial frame result can be obtained as a single lens one of two things is needed. Either trial frames must be so designed that the intervals between the lenses are determined with sufficient accuracy, or the optician must be provided with means of measuring the equivalent power of the lenses in his trial frame as used for his test. This equivalent power, if referred to the plane of the cornea, could then be reproduced by means of a single lens of determined form.

Mr H. H. Emsley: It is clear from what we have heard to-night and from what we have seen for some time in the press that there is much mental activity in the sphere of Ophthalmic Optics with regard to best form lenses, etc. The work centres around the problem of translating the findings of the refractionist, who uses flat trial lenses marked on the ordinary neutralisation basis, into lenses of different forms—toric, meniscus, best form, etc.—that will have the same effect as the trial lenses, which are flat. Since thickness, form, and distance from the eye have to be considered, this translation involves the use of tables and charts that appear to become complicated from the point of view of the factory. One begins to wonder about the overhead expenses. Cannot something be done from the refractionist's end of the work? Is it necessary to leave him to use the same methods that he has used for some considerable time? This is all part, however, of the need for general standardisation of this work. I would hasten to add that the ingenious work done by Mr Swaine and Mr Whitwell is necessary—it is all part of the general progress; I certainly do not agree with a former speaker that we should merely use what we have.

Mr Swaine: I have mentioned in the paper that tables are of no use and do not suggest the employment of any. The tables given are simply to demonstrate the magnitudes of the errors introduced by present day approximations. Whilst vertex focometers have been adopted generally in Germany and introduced in America, as I point out in the paper, the small neutralising set of Messrs Stigmat, Ltd., should be very acceptable.

* A. Whitwell, *Optician*, Jan. 21, 1921.

I do not see the necessity of determining equivalent powers. Any changes of origin can readily be obtained with the aid of the reciprocal rule. The main value of the latter however is that more accurate transpositions are obtainable (than the present thin lens figures) and only occupy two or three seconds longer, whilst vertex relations are especially suitable in practice.

Owing to the convenience of using a slide-rule of general application and rapidity of manipulation overhead charges will not be affected seriously. In my opinion standardisation is required at both ends—refractionists' and manufacturers'. At least the manufacturer should be able to produce a lens to the requirements of the refractionist and this can be done with negligible additional labour.

A speaker has remarked that the effects are negligible. A reference to the paper will show that this is not so and both Mr Raphael and Mr Ryland acknowledge this implicitly. The cumulative errors arising are shown during the course of a review of Dr von Rohr's "Die Brille als optisches Instrument" in a recent issue of the *Optician* (Jan 5, 1923, p. 311).

THE "OCENTRIC" EYE-GLASS

By HENRY C. RAXWORTHY

I would take the opportunity of congratulating the Optical Society on what I might term "harking back" to ophthalmic optics, because I know it has pained the ophthalmic branch to see what they consider a preponderance given in your deliberations to that side of the science dealing with optical instruments.

Great emphasis has this evening been brought to bear upon the absolute necessity of eliminating the multiplicity of common errors in ophthalmic lenses, but it goes without saying that if the most perfect lens is mounted unscientifically its fine qualities are of little avail.

Fig. 1.

The word "Ocentric" is derived from "ortho" meaning correct, and "centric" meaning centered, but the combined word "orthocentric" could not be registered as it described the article, and so the abbreviated form was adopted. The reason why it is called a correctly centered eye-glass is that its measurements can be taken with equal facility whether the eye-glass is off or on the face, which is not the case either with the "astig," which has closer centres when off the nose than on, or the bowspring type, in which both the axes and the pupillary distance differ when off and on the nose. This particular feature of the "Ocentric" is brought about by the fact that the lenses when opened out to place on the nose move about a vertical axis (see Fig. 1), which is the only way to open the plaquets properly, for if the

lenses are pulled apart as in the other types I have mentioned the straps are strained and the plaquets only open slightly at the bottom.

The "Ocentric" is made in eight or nine different styles and the above conditions operate in each pattern. I propose dealing with each variety *seriatim*.

The "Ideal" or low-drilled variety, series 100 (Fig. 2): In the rimless form of this style the lenses are drilled about 20° below the horizontal line, as the clamps are attached at the bottom of the plaquets, and in order to permit of the lenses sitting

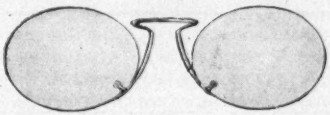


Fig. 2.

higher or lower on the face the plaquets are shortened or lengthened as the case may be. The standard length of plaquets is 15 mm. long; the standard short plaquet is 13 mm., and the standard long plaquet is 18 mm. It will be seen that in using a 13 mm. plaquet the pupillary distances are shortened as the angles remain the same. Correspondingly the pupillary distances of the long plaquet mountings are increased. Should a narrow plaquet width be desired with a larger pupillary distance for a given size of lens the plaquet metal is extended laterally to set the lenses wider apart. To set lenses farther from or closer to the eyes the lens straps may be soldered to the mount in various positions as desired. By means of these two devices (extensions and positions of straps) the same unlimited range of fittings can be given to the "Ocentric" as that given by a spectacle bridge, and this without any extra cost for posts or brackets, as with many other types of eye-glass.

The "Double-Strap" pattern, series 800 (Fig. 3): This is the same pattern as the "Ideal" but, instead of a single strap, it has a double one connected by a thin strip of metal, which has the great advantage that, however badly treated the eye-glass is, the lenses never work loose in the strap.

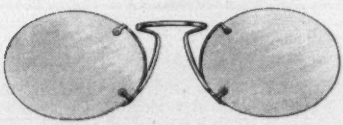


Fig. 3.

Fig. 4.

The "Central-Drilled" pattern, series 300 (Fig. 4): In this style the metal of the plaquets is bent back at the bottom and continued half-way up towards the spring and receives the strap in such a position that lenses drilled on the horizontal axis may be used. Owing to the fact that space has to be found for this "return end," the pupillary distances are 2 mm. wider than with the "Ideal" pattern.

The "Central-Drilled" pattern, series 400 and 700: In the series 400 (Fig. 5) a short bracket connects the strap with the centre of the plaquet, and in the series 700 this bracket takes the form of a swan-neck or telescoped S (Fig. 6). This latter variety is an extremely useful device because the pupillary distances can be altered independently of the distance between the plaquets and *vice versa*. The lenses can be placed nearer or farther from the eyes, and may also be angled to any desired position by elementary plier work. Longer or shorter plaquets may be used, but owing to the fact that the straps are on the horizontal axis and are attached to the centre of the plaquet the drop is only half the increased length of the plaquet.

Fig. 5.

Fig. 6.

Fig. 7.

The "Top-Drilled" style, series 500 (Fig. 7): This is the very latest model and has been specially designed to give as large a lens as possible for a given plaquet width and pupillary distance. It gives an increase of 4 mm. in the length of the horizontal axis as compared with that of series 200 (the "Ideal" pattern with 18 mm. long plaquets). The 500 style is intended to take the place of the 200, because it will be seen upon reference to the chart given below that the latter gives an increased pupillary distance (and therefore a smaller size lens for the same pupillary distance) for the corresponding guard-width. For instance, take a patient requiring two pairs of glasses, one for reading and one for distance; he might have a 150 mount for distance, pupillary distance 60 mm., and would therefore require for reading a 250 mount with a pupillary distance of 58 mm. A 250 mounting with the same size lens as a 150 will give 62 mm., and it will be seen that the 550 will give exactly what is required.

The numbering system. Each fitting has a three-figure number, the first figure of which denotes the pattern, the second the guard-width, and the third offset or flush. The patterns are numbered as follows:

Ideal 13 mm. plaquets, series 0 (Fig. 2).
Ideal 15 mm. plaquets, series 100 (Fig. 2).
Ideal 18 mm. plaquets, series 200 (Fig. 2).
Central-Drilled (bent up plaquets) 15 mm. plaquets, series 300 (Fig. 4).
Central-Drilled (straight bracket) 15 mm. plaquets, series 400 (Fig. 5).
Central-Drilled (swan-neck) 15 mm. plaquets, series 700 (Figs. 5 and 6).
Top-Drilled 15 mm. plaquets, series 500 (Fig. 7).
Ideal (double-strap) 15 mm. plaquets, series 800 (Fig. 3).
Ideal (double-strap) 18 mm. plaquets, series 900 (Fig. 3).

The guard-widths are numbered 1 to 8, which number equals half the number of millimetres between plaquets at top. Thus a guard-width No. 5 has 10 mm.

between plaquets at top. Of the units figures in the fitting number 5 stands for flush, viz. lenses in normal position before the eyes, and 0 stands for offset, viz., 3 mm. farther from the eyes than flush. Should the distances from the centre of the bridge of the nose to the pupils be asymmetrical, a short extension piece to one side of the mount compensates any difference.

It will be of interest to note that the "Ocentric" eye-glass is made at the works of the British Ocentric Optical Co., Ltd., 9–13, Eagle Street, London, W.C. 1.

"Ocentric" Chart showing Minimum Pupillary Distances for various eyes in combination with any fitting.

Top mm.	Bottom mm.	Plaquets 15 mm. long Series 100	400	700	800	1 Eye mm.	0 Eye mm.	00 Eye mm.	000 Eye mm.
6	14	130 135	430 435	730 735	830 835	53	55	56	57
8	16	140 145	440 445	740 745	840 845	55	57	58	59
10	18	150 155	450 455	750 755	850 855	57	59	60	61
12	20	160 165	460 465	760 765	860 865	59	61	62	63
14	22	170 175	470 475	770 775	870 675	61	63	64	65
16	24	180 185	480 485	780 785	880 885	63	65	66	67

		Plaquets 13 mm. long Series 0	Top mm.	Bottom mm.	Plaquets 15 mm. long Series 500				
6	12	030 035	6	14	530 535	51	53	54	55
8	14	040 045	8	16	540 545	53	55	56	57
10	16	050 055	10	18	550 555	55	57	58	59
12	18	060 065	12	20	560 565	57	59	60	61
14	20	070 075	14	22	570 575	59	61	62	63
16	22	080 085	16	24	580 585	61	63	64	65

		Plaquets 18 mm. long Series 200	Top mm.	Bottom mm.	Plaquets 15 mm. long Series 300				
6	16	230 235	6	14	330 335	55	57	58	59
8	18	240 245	8	16	340 345	57	59	60	61
10	20	250 255	10	18	350 355	59	61	62	63
12	22	260 265	12	20	360 365	61	63	64	65
14	24	270 275	14	22	370 375	63	65	66	67
16	26	280 285	16	24	380 385	65	67	68	69

These pupillary distances are minimum, but any size larger can be obtained either by longer lenses or by extensions to the mount.

ON THE AVAILABLE MEANS FOR CORRECTING CASES OF CONSIDERABLE ANISOMETROPIA

By Professor M. von ROHR

More than ten years ago a case with considerable anisometropia presented itself at the Eye Infirmary of Jena University; whereas one of the patient's eyes was emmetropic, the other was corrected by putting $-7\,D$ into the trial frame. One may imagine that the eyes did not work well together, as the patient, a student, was

not in the habit of wearing glasses. It was not to be wondered at that, after correction of the myopia, stereoscopic vision was found wanting, for, according to Fig. 1, the angles of rotation, w', of the corrected eye were much smaller than those, w, of the normal. In contemplating an object of a certain height a difference in the apparent magnitude was to be expected. The following lines will show the amount for an ordinary spectacle glass of -7 *D* corrected for astigmatism of oblique pencils:

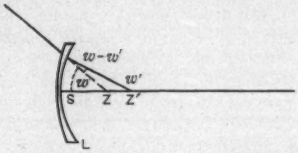


Fig. 1. On the alteration $w - w'$ of the angle of rotation w at the centre Z' by means of a correcting glass of negative focus: a distant object appearing to an emmetropic eye at an angle w is seen by the user of this correcting glass at an angle w'.

$w' = 0$	$20°{\cdot}7$	$30°$
$w = 0$	$24°{\cdot}6$	$36°$

As you are aware, distortion always creeps in and the angles w' are certainly but inevitably too small. Although some oculists are of opinion that differences in elevation of $3°$ or $3\frac{1}{2}°$ might be overcome by each eye, such a faculty could not be detected in our student; in any case it was wanting during the first experiments. He was therefore unable to derive from the mere correction of his myopia any benefit for his binocular vision.

My opinion being requested, I undertook to prepare for him a special eye-glass calculated in such a way that some conditions for binocular and stereoscopic vision might be more nearly fulfilled, my intention being especially to diminish the difference $w - w'$ between the angles w and w', i.e. between the elevation in the naked and in the spectacled eye. Since after correction the image in the myopic eye appeared to our student somewhat (10 per cent.) smaller than the other, I tackled the problem of finding a correcting glass which would magnify the retinal image about 1·1 times. Apart from this the glass should give punctiform images within a field of rotation of $2 \times 25°$ and be exempt from distortion or perceptible chromatic aberrations.

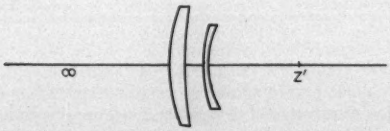


Fig. 2. Section through the axis of a spectacle system (giving punctiform images for anisometropia, $A_\infty = -7$ dioptres.

The glass had the form depicted by the axial section of Fig. 2, showed the magnification of 1·12 and gave the following conjugate angles:

$w' = 0$	$17°{\cdot}39$	$25°$
$w = 0$	$18°{\cdot}66$	$26°{\cdot}69$

From these figures you will see that in proposing this construction I had reduced the former values of $w - w'$ to less than half their amount but had not eliminated them completely.

Our patient, however, was not very interested in our plan; he could not be persuaded to make the necessary stereoscopic experiments, and finally he remained away, fearing, perhaps, that the somewhat conspicuous form of this special construction might injure his outward appearance. You will easily imagine that we were not satisfied to leave the whole matter in such an undecided state, and as we were experimenting at that time with Fick's contact glasses it occurred to me that I might correct one of my own eyes (each having nearly $-7\ D$) by means of a suitable contact glass and use for the other at first an ordinary punctiform spectacle glass of $D_1 = -7$ dioptres and secondly the system described above.

I was then not able to wear the contact glass longer than about half an hour at a time, so that a suitable patient with one naturally emmetropic eye might possibly have learned to overcome still greater angular differences. With the ordinary thin lens I had, under the circumstances described, quite a peculiar sensation; although I had not absolutely lost my sense of depth, it was much impaired, and the perception of space was unwonted as well as rather troublesome; nothing like my

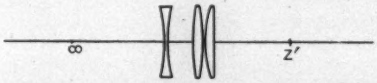


Fig. 3. Section through the axis of a spectacle system (giving punctiform images) for an aphakic eye, $A_\infty = 13$ dioptres.

ordinary good stereoscopic vision was possible under these circumstances. The second trial was far more satisfactory; within the smaller field of direct vision I could immediately fuse both images, and the stereoscopic vision was of nearly the same certainty as with my ordinary spectacles.

On the whole I was not dissatisfied with this result, but I did not continue the experiments with this difference of $7\ D$, because a case far more interesting and important presented itself, where one eye had been operated on for traumatic cataract, the other remaining emmetropic. I took a value of $13\ D$ as the difference between the refractions of both eyes and insisted at that time on the condition of equal size for both retinal images. For the new system I wanted correction for astigmatism of oblique pencils as well as for distortion within $w' = 25°$ and, as in the former case, the absence of perceptible chromatic aberrations.

Such a system belonged to the type shown in Fig. 3. The positive member had to be formed of two single lenses in order to get a good correction of astigmatic aberrations with spherical surfaces only.

As I wish to show the prismatic effects as clearly as possible, I shall give first the values for a Gullstrand cataract lens computed and manufactured by us:

$w' = 0°$	$17°{\cdot}39$	$25°$
$w = 0°$	$11°{\cdot}5$	$15°{\cdot}8$

whereas in the new lens for an anisometropia of 13 *D* the corresponding angles on the object side have the values

$$w = 0° \qquad 14°{\cdot}19 \qquad 20°{\cdot}7$$

It would easily have been possible to make the values of w approach much closer to those of w', but we should then have had to disregard the condition of equally-sized retinal images. At that time, however, we considered such a deviation as unjustifiable and had to experiment with the system shown in Fig. 3.

Dr H. Erggelet, who has emmetropic eyes of a high acuity and enjoys perfect stereoscopic vision, made one of his eyes temporarily hypermetropic, requiring a correcting glass of $D_1 = 13$ dioptres. He used a contact-glass for this purpose and was able to wear it for some time, from 25 to 30 minutes. In 1913 we could make these contact-glasses in a primitive form only, so that the movement of the eye-lid sometimes dislodged the contact-glass. However, to form a general impression, these old contact-glasses answered well enough. If Dr Erggelet corrected his artificial anisometropia by means of a bi-convex or a Gullstrand cataract-glass of 13 *D*, he was much troubled by double images and binocular vision was hardly* possible. But as soon as he chose the new system for anisometropia, binocular vision was restored and the anisometrope found himself much relieved.

Carl Zeiss has made some such lenses, mostly for young people operated on for traumatic cataract; they have given satisfaction, as communications from Drs Hegner, Loewenstein, and Wolff have shown. I shall, however, here point out an interesting paper by Dr R. G. Rijkens†, a Dutch physician, then at Zutphen. Dr Rijkens had just been operated on for cataract and had naturally lost stereoscopic vision when he used his single correcting lens of + 9 *D*. With a system for anisometropia as described, however, he was well able to solve some stereoscopic tests, provided the angular value of the stereoscopic difference was not smaller than 4 minutes. As his visual acuity on the couched eye was 1/3 only (there were large maculae corneae on it), the effect of the system may be considered satisfactory. We may attach rather greater value to these results, as Dr Rijkens is eminently qualified to give a decisive judgment, and as all the minor objections against the somewhat uncertain position of the contact-glass do not apply in this case.

But an anisometropia of 13 *D* is not the highest difference that may be successfully overcome in order to restore stereoscopic vision. Four years ago Dr H. Wolff of Berlin requested our help for a patient of his who had − 20 *D* in the left eye and zero power—in consequence of an operation for cataract—in the right. As the visual acuity was low, he wished that his patient might obtain some magnification of the retinal images. In other words, telescopic spectacles were to be constructed for an anisometropia of 20 *D*.

At my suggestion Dr Boegehold directed the trigonometrical calculations in

* He observed, however, that small objects in the distance, a water tap for instance, could be seen stereoscopically notwithstanding the great difference in the size of the pictures. He has now taken up this problem and anyone who is interested in it may find some useful directions in his paper, "Versuche zur beidäugigen Tiefenwahrnehmung bei hoher Ungleichsichtigkeit," *Klin. Mtsbl.* 66 (1921) 685.

† "Meine Erfahrungen mit der Anisometropbrille," *Z. f. ophth. Opt.* 4 (1916) 146.

such a way that the principal stress was laid on balancing the w and w' angles, whereas a deviation in the size of the retinal images was of secondary consideration. The effect was very satisfactory. Dr Wolff* could show that his patient with so great an anisometropia had good stereoscopic vision. He says of him: "The patient is continually wearing his spectacles for anisometropia in going about as well as in driving his motor car. Whereas he formerly was of pale, depressed, clumsy, and neglected appearance, he is now a happy, well-dressed and adroit person, with whose joyful and ruddy countenance the pair of rather thick spectacles agree quite well."

I think we are entitled to conclude that with the new means at our command certain patients might recover their otherwise lost stereoscopic vision.

DISCUSSION

Mr W. Swaine: Equality of retinal image is alone considered. The problem with regard to high cases of anisometropia appears to me to be: What should receive first consideration? Authorities appear to differ as to whether the inequality of accommodation when corrective lenses are used in near vision, convergence troubles, or unequal magnifications require first consideration. Further research is desirable.

For the prescribing of lenses as here described the actual retinal images must be examined presumably by Messrs Zeiss's recent instrument. British practice is only at the stage of ensuring conjugacy of retina and distance.

Professor v. Rohr (communicated): I am not sure whether I have expressed my meaning quite clearly. I started from the equality of both retinal images, but during the experiments it seemed as if an approximate equality of the angles of rotation for both eyes was of greater importance. If, for the sake of brevity, I suppose one of the eyes emmetropic, I should like to put the condition as w approximately equal to w' for a comparatively large field, whereas the size of the retinal images seemed of secondary importance only.

ON THE BEST FORM OF SPECTACLE LENSES FOR THE CORRECTION OF SMALL AMOUNTS OF ANISOMETROPIA

By A. WHITWELL, M.A.

When an observer having emmetropic eyes views a near object the two eyes move round their centres of rotation and their axes converge and intersect in a point on the object. Wherever this point may be, two rays drawn from it through the two centres of rotation of the eyes are the chief rays or axes of small pencils of rays which form images of the object point on the maculae of the two eyes. If a line drawn through the two centres of rotation is supposed to be an axis round which a plane rotates, this plane will sweep over every point in space and will always contain the axes of pencils of light which form images on the maculae of the two eyes.

* "Ausgleich höchstgradiger Ungleichsichtigkeit von 20 D durch die Rohrsche Anisometropie-Fernrohrbrille (C. Zeiss, Jena) neuer Art (1917)," *Z. f. ophth. Opt.* 7 (1919) 10.

When the eyes are ametropic and are assisted by spectacle lenses the rays from an object point are in general deviated. If the rays from a point on the object, after refraction by the lenses, pass through the centres of rotation of the two eyes and if the eyes be rotated, so that their axes coincide with the emergent rays, images will be formed on the maculae, but in general the two emergent rays will not be in one plane. If the object point lie in the median plane, that is, a vertical plane bisecting at right angles the line joining the centres of rotation, and the two lenses be of the same power, we shall have symmetrical refraction and the two emergent rays *will* be in the same plane. If the object point lie outside the median plane and two incident rays be drawn from it in such a way that, after refraction, they pass through the centres of rotation then the two emergent rays, in general, will not be in one and the same plane.

This will be evident if we consider the fact that the perpendicular distances of the points of emergence of the chief rays of the imaging pencils (from the axes of the lenses) are different for the two lenses, so that if a plane rotates round the line joining the two centres of rotation till it contains one point of emergence, then it will not contain the other and consequently will not contain both emergent rays. Unless, therefore, the object point be (1) at infinity or (2) in the median plane or (3) in the horizontal plane containing the axes of the eyes and the spectacle lenses, the two emergent rays passing through the two centres of rotation will not be in the same plane.

When the two emergent rays passing through the centres of rotation are *not* in the same plane, in order to fuse the two images the eyes must be moved in an unusual manner, or in a manner in which they are not accustomed or practised to move, and if the angular distance of one of the rays from the plane containing the two centres of rotation and the other ray is too great the eyes are not able to fuse the images and double vision is the result. This effect must be present in all spectacle lenses, even when they are of the same power for both eyes, but I suppose that in most cases it is too small to be noticed. It is due to the different prismatic effect of the two lenses. When the eyes have different refractive powers and consequently require spectacle lenses of different powers for their correction the effect is generally appreciable and requires correction.

In a case of anisometropia, whether the object point be at infinity or near and whether it be in or outside the median plane, the two emergent rays which pass through the centres of rotation are not in general in the same plane and do not intersect. I say in general, because if the object point be in the horizontal plane containing the axes of the two lenses and of the two eyes and consequently containing the two centres of rotation, then the emergent rays are of course in the same horizontal plane with the incident rays; in this case the emergent rays are deviated, they intersect, and the image appears to be displaced, but the eyes do not need to move in any unusual manner in order to fuse the images.

In discussing the correction of anisometropia I shall confine myself, as Dr von Rohr does, to an object point in the median plane. Let us suppose that from a point in the median plane two rays are incident on the two lenses at such points that

after refraction by the lenses the two emergent rays pass through the centres of rotation. As we are assuming the lenses to be of different powers, it is obvious that the points on the axes of the lenses to which the incident rays are directed must be at different distances from the back vertices of the lenses and it is equally obvious that (1) the points of emergence will in general be at different heights, (2) the angles which the two emergent rays make with the axes of the lenses will be different, and (3) the emergent rays will not intersect or be in the same plane.

As is customary in dealing with problems of this nature, I assume the *image point* to be in the median plane and I join this point to the two centres of rotation. I then suppose these two lines to represent emergent rays corresponding to two incident rays. By tracing backwards the given emergent rays I find the angles which the corresponding incident rays make with the axes of the lenses.

Having assumed the angles which the emergent rays make with the axes and calculated by computation the corresponding angles which the incident rays make with the axes, I am enabled to find the deviation of each ray. As all the trouble in anisometropia is the effect of the difference of the deviations in the two lenses, it is necessary to design the lenses so that this difference is zero or as small as possible.

In designing the lenses we can (1) bend the lenses, keeping the power constant, (2) vary the index of refraction, (3) vary the distances from the centre of rotation to the back vertex, (4) vary the axial thicknesses of the lenses, (5) vary the distance between the centres of the lenses (that is to say, decentre one or both lenses). I first tried what would be the effect on the deviation of bending the lenses, keeping the axial thickness and the power (as measured by neutralisation) constant. I took four cases of lenses of powers + 2 *D*, + 4 *D*, − 2 *D*, and − 4 *D*, and calculated the deviation for emergent rays which make an angle $a_2' = 20°$ with the axes. I assumed the index of refraction to be 1·52, the centres of rotation to be 25 mm. from the back vertex, the diameter of the lenses 36 mm., the edge thickness of the positive lenses and the axial thickness of the negative lenses ·5 mm. The power of the first surface of a lens $= \kappa_1 = \frac{\mu - 1}{r_1}$ and that of the second surface $= \kappa_2 = \frac{\mu - 1}{r_2}$ and I considered $\kappa_1 + \kappa_2$ to be constant. The following four tables give the particulars of the computations:

Table I.

+ 2 *D* $\mu = 1{\cdot}52$ $d = 25$ mm.
axial thickness $t = 1{\cdot}1$ mm.

κ_1	κ_2	a_1	$a_2' - a_1$
− 4	+ 6	18°·802	1°·198
− 2	+ 4	18°·820	1°·180
0	+ 2	18°·832	1°·168
+ 1	+ 1	18°·835	1°·165
+ 2	0	18°·835	1°·165
+ 4	− 2	18°·832	1°·168
+ 6	− 4	18°·822	1°·178
+ 8	− 6	18°·807	1°·193
+19	−17	18°·621	1°·379

Table II.

+ 4 *D* $\mu = 1{\cdot}52$ $d = 25$ mm.
$t = 1{\cdot}7$ mm.

κ_1	κ_2	a_1	$a_2' - a_1$
− 2	+6	17°·592	2°·408
0	+4	17°·634	2°·366
+ 2	+2	17°·662	2°·338
+ 4	0	17°·675	2°·325
+ 6	−2	17°·677	2°·323
+ 8	−4	17°·668	2°·332
+10	−6	17°·648	2°·352

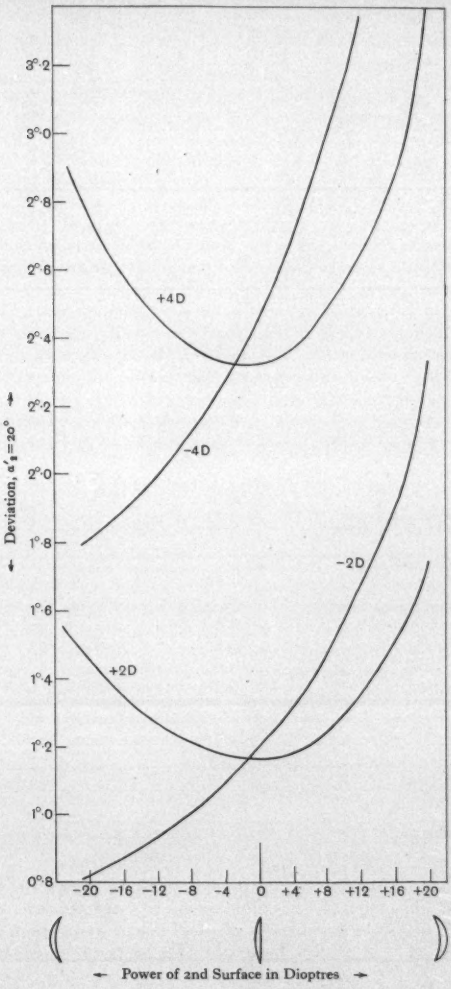

3°·2
3°·0
2°·8
2°·6
2°·4
2°·2
2°·0
1°·8
1°·6
1°·4
1°·2
1°·0
0°·8
Deviation, $\alpha'_{\frac{1}{2}} = 20°$
+4D
−4D
−2D
+2D
−20 −16 −12 −8 −4 0 +4 +8 +12 +16 +20
Power of 2nd Surface in Dioptres

Table III.

$-2\,D$ $\mu = 1{\cdot}52$ $d = 25$ mm. $t = {\cdot}5$ mm.

κ_1	κ_2	α_1	$\alpha_1 - \alpha_2'$
+18·8	−20·8	20°·814	0°·814
+10	−12	20°·934	0°·934
+ 4	− 6	21°·050	1°·050
+ 2	− 4	21°·095	1°·095
0	− 2	21°·144	1°·144
− 2	0	21°·196	1°·196
− 4	+ 2	21°·253	1°·253
− 6	+ 4	21°·316	1°·316
− 8	+ 6	21°·386	1°·386

Table IV.

$-4\,D$ $\mu = 1{\cdot}52$ $d = 25$ mm. $t = {\cdot}5$ mm.

κ_1	κ_2	α_1	$\alpha_1 - \alpha_2'$
+16·8	−20·8	21°·800	1°·800
+ 8	−12	21°·994	1°·994
+ 2	− 6	22°·187	2°·187
0	− 4	22°·266	2°·266
− 2	− 2	22°·355	2°·355
− 4	0	22°·452	2°·452
− 6	+ 2	22°·564	2°·564
− 8	+ 4	22°·688	2°·688
−10	+ 6	22°·829	2°·829

The results given in these tables are plotted in the figure in which the abscissae are the powers of the second surfaces of the lenses in dioptres and the ordinates are the deviations in degrees. It will be observed that when the lenses are positive the deviation is least when the second surfaces are approximately plane. The deviation increases as the lenses become of the meniscus form with either the convex or the concave surface towards the eye. The negative lenses have the least deviation when the second surfaces are strongly concave towards the eye and the greatest deviation when the second surfaces are convex towards the eye.

A study of the four curves enables one to make the following deductions concerning the best form of lens for correcting small amounts of anisometropia:

Eyes	Lenses
One eye emmetropic Other eye hypermetropic	Second surface approximately plane
Other eye myopic	Second surface strongly negative
Both eyes hypermetropic	*Stronger* lens with second surface approximately plane *Weaker* lens with second surface strongly negative
Both eyes myopic	*Stronger* lens with second surface negative *Weaker* lens with second surface positive
One eye myopic Other eye hypermetropic	Negative lens having a strongly negative or concave second surface Positive lens having a second surface plane

Effect of varying the distance of the back vertex from the centre of rotation or, what is the same thing, from the cornea.

In order to find what effect moving the lens further forward would have on the deviation I took the case of a $+4\,D$ plano-convex lens with the plane surface next the eye and calculated the deviation for $\alpha_2' = 20°$ when d, the distance of the back vertex from the centre of rotation, was varied. The result was as follows:

d	$a_2' - a_1$
25	$2^{\circ}{\cdot}325$
30	$2^{\circ}{\cdot}753$
40	$3^{\circ}{\cdot}598$
49	$4^{\circ}{\cdot}348$

The deviation increases almost uniformly with the increase of d. We can use this property for balancing the deviation of two positive spectacle lenses by setting the weaker lens further away from the eye than the stronger one. Similarly I found that increase of the index of refraction and of the axial thickness of the lenses increased the deviation.

Although I have not had time fully to work it out, I have little doubt that decentering *one* of the lenses in a horizontal direction is a means for balancing the two deviations.

In conclusion it appears possible, by the use of the five methods enumerated above, viz. (1) bending, (2) varying index of refraction, (3) varying distance of lens from cornea, (4) varying axial thickness of lens, (5) decentering, so to design simple lenses as to correct or minimise the effect of small amounts of anisometropia. In general it will not be possible to correct at the same time the astigmatism of oblique pencils, but in all cases where the second surface of a lens must be strongly concave to the eye in order to correct the anisometropia, one can select the strongly curved or Wollaston type of meniscus and in this way *also* correct the astigmatism.

NOTES ON THE NON-OPERATIVE TREATMENT OF SQUINT

By MARGARET DOBSON, M.D., Lond.

In ordering glasses for squint the object in view is, firstly, to correct the deformity by making the eyes parallel, and secondly, to prevent the squinting eye from becoming amblyopic from disuse. The treatment must begin as soon as the child can wear glasses. One should aim at curing squint before the child is six years old, as by this time the fusion sense has become established and it is most difficult to obtain binocular vision after this age. If the glasses do not straighten a squinting eye there is a danger of permanent loss of vision in this eye.

The method of procedure in ordering glasses is as follows. For one week a 2 per cent. solution of sulphate of atropine is instilled into the eyes, three times a day. A complete paralysis of accommodation is thus obtained. A careful retinoscopy is now made, and a full correction is ordered. The large majority of squinting eyes are found to be hypermetropic or hypermetropic with astigmatism. Accommodation and hypermetropia are intimately associated; the glasses ordered relieve the hypermetropia, i.e. the contraction of the ciliary muscle which is not even at rest when viewing objects at infinity, or at any distance greater than 6 metres. The glasses should be worn for two years before surgical treatment is adopted.

1. Glasses shqld be worn constantly—large circular lenses, over which the child cannot look, are recommended.

2. A second pair, the practice glasses, in which the lens of the sound eye is covered by a plane disc of vulcanite, should be worn for several hours each day, in order to stimulate vision in the defective eye.

3. A pair of "Triplex" (unbreakable) glasses, made up to the prescription, should be worn during play-time, in order to lessen the risk of injury to the eye from broken glass.

4. Glasses, the arms of which end in loops above the ears, and which can be tied round the head, should be worn by very young children.

5. If astigmatism is present, glasses with banana-shaped brackets resting on the nose are recommended, as displacement of the axes is thereby reduced to a minimum.

A special frame, suitable for very young children, or for motorists, has been devised by the author. It has a very short arm ending in two branches at an angle of 45°. To the end loops of these elastic is attached which passes round the ears.

SIR WILLIAM CROOKES' ANTI-GLARE GLASSES

By J. H. GARDINER, F.Inst.P.

I suppose that I have the privilege of knowing as much as anyone about this subject, having been intimately associated with the late Sir William Crookes for more years than I care to count, working under him in all the researches connected with the glasses that bear his name. Sir William was deeply interested in the subject, and was engaged upon the work at the time of his death.

A few words briefly giving the history of the research may not be out of place. The work on the radiation transmission of transparent substances began with an enquiry into the cause of glass-maker's cataract, and several years of hard work were devoted to it; in 1914 a paper was read before the Royal Society in which formulae were given for many glasses having special optical properties, and manufacturers were encouraged to produce them for general use. As a result, Sir William was inundated with enquiries from private people needing assistance for eyesight trouble, and from glass manufacturers who wished to use his name for glasses that they had succeeded in making from his published formulae.

It soon became evident that further work was necessary to produce a glass that would absorb as much ultra-violet radiation as possible, and at the same time transmit the bulk of the visible rays; the glass also had to be pleasing in appearance. It was evident that it would be necessary to make a variety of tints to suit different climatic conditions.

The work was carried out with the assistance of Mr Harry Powell of Whitefriars Glass Works, whose death unhappily occurred a few days ago. Agreements were made between Sir William and Mr Nelson Wingate, of Wigmore St, W., for the glasses to be placed upon the market as soon as conditions made their production possible. Some of these glasses are on exhibition here to-night. Many causes, that I need not enter upon now, have prevented very large production, but it is

hoped that the output will be increased shortly; the glass is of a very special character and presents unexpected technical difficulties.

On the death of Sir William the whole of the data for the preparation of the glasses, and the apparatus that had been devised for obtaining measurements of the radiation transmitted and absorbed by them, were given into my charge; the apparatus will shortly be erected at the Laboratories of the new Whitefriars Glass Works at Wealdstone, where we hope to be able to produce the material in larger quantities than has been possible at the old works in London.

DISCUSSION

Dr L. C. Martin: I would like to draw attention to the work of Verhoeff and Bell on the "Pathological Effects of Radiant Energy on the Eye" (*Proc. Amer. Acad. Arts and Sciences*, 51 (July, 1916), No. 13). A systematic review of the literature is given by Dr C. B. Walker in the same issue. The authors show that the radiations possessing "abiotic" power (or power of destructive action on living tissue) are confined to wave lengths shorter than ·305 μ. It is under exceptional conditions that such harmful action can be caused by sunlight which possesses very little energy at ·305 μ and contains no wave lengths shorter than ·295 μ at the earth's surface owing to atmospheric absorption. Similarly the possibility of abiotic action with the light from ordinary enclosed sources of artificial light is very remote, although with naked arcs, etc., special protection must be given.

In ordinary life the causes of eye strain and inflammatory conditions must be sought in conditions other than the abiotic action of light and attention would be better directed to the regulation of the intensity of the visually apparent radiations, to general health, and to the provision of proper refractive correction. The conclusions set out in my paper on "Light Filters for Eye Protection" (*Trans. Opt. Soc.* 18 (April, 1917)) agree with those of Verhoeff and Bell and I would like again to draw attention to that paper in the present connection.

Mr H. H. Emsley: I associate myself with Dr Martin to the extent of expressing some confusion of mind as to what exactly Crookes' glass is intended to do. My recollection of Crookes' work on the subject is that it was found that cataract in glass-workers' eyes was caused by the infra-red radiation and not by the ultra-violet. Nowadays one hears no word about the infra-red absorbing properties of the glass. It is true that Crookes extended his investigation as he proceeded and encountered many difficulties, but I am not clear as to why the ultra-violet is continually referred to and practically nothing is stated about the infra-red.

THE MANUFACTURE OF GOLD-FILLED SPECTACLE FRAMES

By HERBERT S. RYLAND.

Gold-filled spectacle and eyeglass fittings are probably more used than those made of either steel or gold. They were designed to meet the need for a material which could be sold at a price within the reach of all and yet have the wearing and

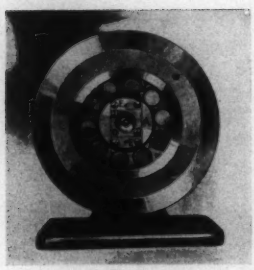


Fig. 1.

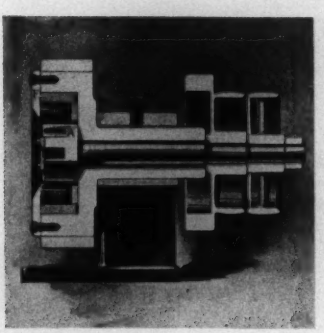


Fig. 2.

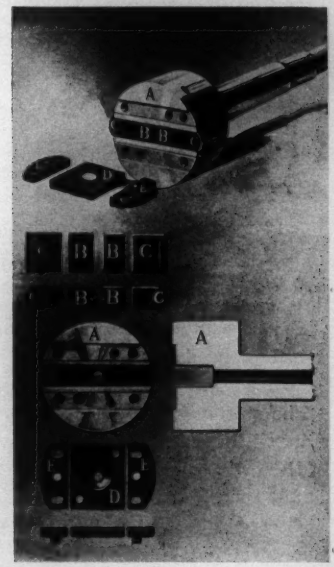


Fig. 3.

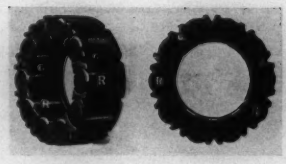


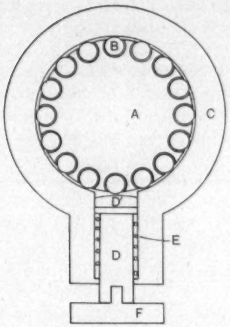
Fig. 4.

non-corrosive properties of solid gold. Any part of a gold-filled spectacle frame consists of two portions, one completely surrounding the other. The inner portion is a base metal alloy in which copper plays a large part, and the outer is usually a gold and silver alloy. The quality, apart from manufacturing details, is determined by the proportion between the weight of the two alloys and the value in carats of the gold alloy. It is usually expressed in the form 1/10 10 carat. The quality, as determined by the actual manufacture, depends upon the completeness, or non-perforation, of the gold casing, the fit of the various working parts, and the ability of the frame or mount as a whole to retain its shape. Unlike steel, gold-filled material cannot be hardened or tempered by heat, but, like solid gold, it can be hardened by hammering or rolling.

Gold-filled material is, like gold or steel, prepared in the form of wire, tube, and sheet. It is interesting to note that the weight and carat value of the material are maintained in well-made goods from the stock to the finish of each individual part. This being so, it is evident that the usual methods of cutting, turning, filing, etc., used for solid metal, cannot be employed here. For this reason special methods and machines for shaping the various parts have been developed. The different processes may be summarised as follows:

(1) *Swaging*. Swaging is a process of hammering, by means of a special machine and suitable dies, wire or tube either to a smaller size or to a taper or other predetermined form. Figs. 1 and 2 show end and longitudinal sections of a swaging machine, some of the parts of which can be seen in Figs. 3 and 4. A spindle *A* (Figs 1–3) is provided with a slot which carries the dies *B* and steel blocks *C* (Fig. 3), called backers, with rounded ends. These are held in position by cover plates *D*, *E*. The dies are in the centre of the slot so that the axes of the forming groove and the spindle are coincident. Surrounding the part of the spindle which carries the dies is an annular rack *G* (Fig. 4) carrying a number of hardened steel rollers *R*. The rack is enclosed in a heavy stationary cylinder (Figs. 1 and 2). When the spindle is revolved the backers pass between successive pairs of rollers and are forced on to the dies. The work is prevented from revolving while the spindle revolves rapidly; at the same time the rack is free to revolve, but is only moved by the passage of the dies and the backers. Hence it moves slowly in comparison with the spindle; as a result the dies close upon the work each time in a different circumferential position, and the work retains its cylindrical form. The spindle itself is hollow so that long pieces of wire may be passed through when necessary. In order to prevent the perforation of the gold outer casing of the work it is essential that the dies be well polished and that the machine be kept free from grit and dirt.

(2) *Hammering*. The hammer machine is used for making the elliptical joints of "astig" frames or for flattening parts of pieces of wire intended for use as springs. In principle it is similar to the swaging machine. A diagrammatic view is shown in Fig. 5. *A* is a revolving spindle with grooves cut in it to carry the rollers *B*, which are therefore carried round by the spindle. The spindle and rollers are enclosed in a heavy casing *C*, which is fitted with a slot to carry a die holder *D*. The upper end of the die holder is fitted with a rounded hard steel block *D'* and is



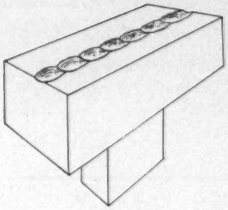


Fig. 6.

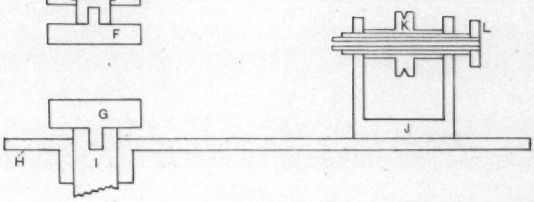


Fig. 5.

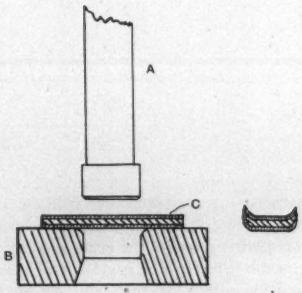


Fig. 7.

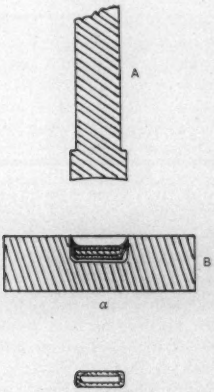


Fig. 8.

kept against the rollers by a spring *E*. The whole is mounted on a strong table *H* carrying a lower die holder *I*, which is lifted towards the upper holder by means of a pedal-operated lever. If the lower die holder is lifted against the upper as the spindle revolves the passage of each roller delivers a blow to the dies *F* and *G*, and to the work held between them. In this manner as many as five thousand blows per minute may be delivered to the work. In the case of cylindrical pieces it is necessary for the work itself to revolve. The machine is provided with what is in effect a lathe head *J* having a hollow mandrel *K*, fitted with draw-in chucks *L* to grip the work. This makes it possible to revolve the work during the hammering operation.

As an example of the work performed on this machine we may consider the elliptical joints used for "astig" frames. The dies used are shown in Fig. 6. The stock is a gold-filled tube, that is, a tube of base metal having a tube of gold on the outside. A piece of steel piano wire is drawn through to act as a mandrel. The whole is gripped in the lathe head and revolved between the dies. The lower die is then forced towards the upper by means of a foot pedal until the dies are closed. This process is repeated over the whole length of wire. The piano wire is then withdrawn, and the ellipses, if the dies are correct, can be broken apart with the fingers. Just as noted for the swaging machines, freedom from grit and well polished dies are necessary conditions for good work.

(3) *Pressing*. We now come to press work. Press tools are used for cutting sheet metal to shape, an operation known as blanking; bending sheet metal or wire to a given form; embossing or impressing a given surface form on a piece of metal; or drawing, that is, making tubes or cups from sheet metal. For gold-filled work in such parts as joints a tearing, rather than a cutting, action is needed so that the gold casing may be brought up over the edge. To accomplish this the dies are made with rounded edges as shown in Fig. 7*a*, *A* being the punch, which is operated by the ram of a press, and *B* the die. It will be noticed that the gold casing of the work *C* is on both sides of the plate. Some makers use metal with gold on one side only. The work after pressing is shown in section in Fig. 7*b*. It will be noticed that the gold is drawn up over the edge from the bottom while the upper gold is torn up before the joint is finally separated from the stock. To close the gold down and at the same time square up the joint an embossing die (Fig. 8*a*) is used. The punch *A* has a slightly concave lower surface and fits the depression in the die *B*. As a result the metal of the joint is forced out to fill the depression in *B* while the slightly concave lower surface of the die closes the gold down as in Fig. 8*b*, thus making the joint acid proof except for the screw holes. Both the die and the lower surface of the punch must be polished; edges and corners must be slightly rounded.

An example of bending is shown in Fig. 9; in this case the wire *C* for a spectacle bridge is simply bent to form between the punch *A* and the die *B*, the wire having been previously flattened for the crest and spread, for soldering to the eye wire, in an embossing die. In bending such a piece as this allowance must be made in the shape of the dies for the tendency of the wire to spring back to a certain extent towards its original form. An example of an embossing die is shown in Fig. 10.

This die, as its form will indicate, is for producing bars for "astig" frames. The round wire is laid in the groove *cd*, and the punch, which has a flat lower surface (with the exception of a groove to clear the round portion of the bar *ce*) is forced down. That part of the wire from *e* to *d* is thus spread to fill the half round groove end. A point of interest to note here is that the wire after flattening is always slightly larger than the groove in the die, owing to the elasticity of the metal. Careful allowance for this must be made when the die is designed.

For producing a cup, such as that for the end of a "temple" or cable side, the punch is smaller in diameter than the hole in the die by an amount slightly less than twice the thickness of the stock, and the edges both of punch and die are slightly rounded. The work is kept flat until it is drawn down by the punch, thus preventing the formation of wrinkles in the sides of the cup.

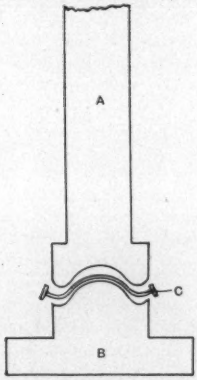


Fig. 9.

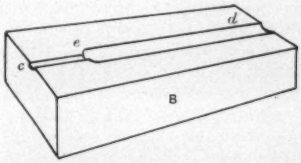


Fig. 10.

(4) *Winding*. Cable sides consist of a central wire round which wires, usually four in number, are wound by means of a special winding machine. This consists of a revolving plate to which are attached four spools of wire which are free to rotate as the wire is wound off. The mandrel or core upon which the spiral is formed consists of a length of steel piano wire which is moved along the hollow axis of the plate. Means are provided for adjusting the tension of the wires and the speed of the core.

(5) *Soldering*. Hard soldering plays a large part in the assembling of spectacle goods. It is called hard soldering because the melting point of the solder used is but little less than that of the material soldered. The older method of obtaining the heat for soldering was to use a gas blow-pipe. For factory purposes, air, compressed by a power-driven compressor, was supplied to the blow-pipes by means of a pipe line led to the work benches.

The heat of soldering has the effect of softening the spectacle frame in the region of the joint. Where the gas blow-pipe is used this softening may extend for some distance on either side. In some cases the softening can be partly remedied by a final hammering, but this is not always possible.

For this reason electric soldering machines are now being used. The machine consists essentially of a pair of heavy clamps by which the work is held as close to the joints as possible. These clamps are connected through an adjustable resistance, ammeter, and switch to a supply of current. The minimum current required to melt the solder is found by experiment for each part to be soldered. This is noted, and the resistance adjusted accordingly for each batch of work. There are three advantages attached to this method of soldering:

(1) the process is speedy,

(2) temperature conditions are under perfect control,

(3) the extent of the heating, and consequently the extent of the softening, is reduced to a minimum.

The cleaning of the work after machining is conveniently done by suspending the parts from an iron wire in a caustic solution and passing a small current through them. Another method is to pack the parts in perforated containers which are kept in constant movement in a hot lye solution.

The final process may be either gilding or polishing, but if the machining has been properly done, gilding should be unnecessary.

Were it not for its corrosive properties, steel for spectacle work would probably be used to a greater extent than it is. There are available to-day what are known as black nickelling and stainless steel. The use of one, or both, of these would provide a spectacle frame which has the stiffness which is so desirable, together with a dull black finish. No doubt some of our manufacturers will take this question up.

This paper is not intended as a detailed technical description of the manufacture of gold-filled spectacle goods; it is hoped however that this general description of special mechanical methods, not generally known, will be of interest, as the author can see nothing to prevent the establishment of a very considerable industry in this country.

EXHIBIT OF A PRISMATIC ASTROLABE

By Instructor-Commander T. Y. Baker, R.N., B.A.

Exhibited 8th February, 1923

This instrument, which is used for accurate geodetic survey work, was designed and made at the Admiralty Research Laboratory, Teddington; it is a modification of that designed by MM. Claude and Driencourt and extensively used in the survey of Egypt.

The general principle of the instrument is embodied in the use of a prism of 60° angles placed with its edges horizontal in front of a horizontal telescope, the face nearest the telescope being vertical. Below, and slightly in front of the prism, is a mercury trough. When the instrument is turned into the azimuthal plane of a star whose altitude is about 60° above the horizontal two images of the star are visible through the telescope, the one seen by light transmitted through the upper slant face of the prism and subsequent reflection at the lower slant face; the other by light reflected first in the mercury surface then transmitted through the lower slant face and subsequently reflected at the upper slant face. The two star images move one upwards and the other downwards in the field of view as the star rises or sets and the instant when they come into contact is the instant when the star is at an altitude of 60° if the front edge of the prism is exactly 60°.

The modifications made at the Admiralty Research Laboratory are two-fold. (1) The prism is made rotatable about an axis parallel to its edges and the angles of the prism are allowed to depart slightly from 60°, being actually in the model shown 60° 4′ 21″, 59° 59′ 43″, and 59° 55′ 56″. By using each edge of the prism in turn as the front edge three observations of the star can be made instead of only one, the mean of the measured altitudes being exactly 60°. (2) A refracting prism of small angle is mounted to cover one quadrant of the object glass and a duplicate image of one star is thus produced in the field of view. The duplicated images are on the same horizontal level. The observation for contact is made by noting the instant when the descending image is on a level with and between the duplicated images, instead of noting the instant when two star images come into exact contact, as was done in the old instrument. Laboratory trials of the two methods show that whereas the mean error of observation with the old scheme was 0″·2, with the new arrangement the mean error is 0″·12.

REVIEWS

Die Brille als Optisches Instrument. By Professor M. von Rohr. Pp. xiv + 254; 112 figs. (Berlin: Julius Springer, 1921.)

The first edition of this book (1911) has been revised and enlarged in this edition—the third. Dr von Rohr has rendered a valuable service both to those who specialise in the application of ophthalmic lenses and to the physical historian. Almost every alternate paragraph is associated with historical notes which are so well indexed as to yield a valuable bibliography. It is peculiar, however, that no mention is made of the acknowledged doubtful inventor of spectacles, whether Friar Bacon or otherwise.

The introductory remarks occupying some seventeen pages are mainly concerned with protective goggles, tinted and eye-preserving glasses, and spectacle novelties such as contact lenses. One would have thought that the theory of annoying reflections occurring at the spectacle surfaces was worth more consideration than is given to it.

The second part on spectacle lenses constitutes the major portion of the work and after describing various "shapes" of lenses, lenticular forms, etc., in detail is subdivided into Anastigmatic and Best Form Lenses, cylindricals and torics, chromatism, and binocular vision through spectacles. References in this portion are particularly copious. The matter presented possesses considerable theoretical interest but may fail to satisfy the more precise requirements of the practical worker. Commencing with a definition of vertex refraction, the writer immediately converges to a cardinal treatment of spectacle lens in combination with the Gullstrand schematic eye. The Gullstrand treatment of visual acuity in aided vision is next considered. One ventures to think that a direct attack (e.g. Donders) on the influence of correcting lenses on the apparent amplitude of accommodation gives a simpler and more fundamental solution of this problem.

The Best Form problem is discussed at great length and is especially worthy of note. After considering the function of the centre of rotation and orthoscopic conditions there follows a decidedly useful review and criticism of the first approximations of Ostwald, Tscherning, Percival, Whitwell, and others. There is, however, no British reference in the whole book dating after 1915, so that Whitwell's important article "Best Form XV" (*The Optician*, Oct. 3, 1919) is not included—the article in question gives the marginal astigmatism for a whole range of spectacle lenses on various bases as obtained by more rigorous trigonometrical computation. Gullstrand's aspherical lenses are not treated very fully. The influence of the position of the centre of rotation on the bending of the lens is shown clearly in a fairly long paragraph.

The section on astigmatic and toric lenses is very suggestive, e.g. the question of astigmatic distortion. The last section of the second part of the book should be read by those prescribers of lenses who rely too readily on the patient's perseverance to "get accustomed to the lenses," a stratagem rather common in this country and America. Other points worthy of note are the treatment of prismatic spectacles and the decentration of all kinds of lenses, telescopic, achromatic and anisometropic spectacles.

The last section of the work reviews the ophthalmic activities of the various countries, and England does not compare very favourably with either America or Germany. The view of England's work is justified but one would have thought America warrants more consideration.

W. S.

Sprechsaal-Kalender für die Keramischen, Glas- und verwandten Industrien, 1923. (Coburg: Müller and Schmidt.)

The technical part of this Annual, which is now in its fifteenth year, contains over 240 pages of physical and chemical data compiled by Dr J. Koerner, editor of the *Sprechsaal*. While much of the information contained in the calendar is of general utility, the major portion is of special interest to those interested in the manufacture of glass or ceramics. Analyses of various raw materials from Continental sources suitable for use in these industries are included and also a very full list of melting temperatures and physical characteristics of various compounds and eutectic mixtures, together with their molecular and percentage composition.

Several processes, for example, the plating, etching and cementing of glass, are described in detail. The section on optical constants has been brought up to date by the inclusion of results recently obtained by Peddle and other workers in this subject. The durability of glasses is also dealt with but not quite so fully.

The glass or ceramic technologist who is able to read German will find the book very useful in providing necessary data in a readily accessible form.

F. F. S. B.

ABSTRACTS OF PATENT SPECIFICATIONS

183145. Gasser, M. STEREOSCOPIC APPARATUS.

Overlapping oblique photographs are mounted upon carriers which are adjusted in correspondence with the positions from which the photographs were originally taken. The field is then explored by adjusting the carriers in such a way that corresponding image points are seen by reflection in coincidence with a mark on a vertical graduated staff, which mark indicates the altitude of the point, while the foot of the staff gives its position in plan. One reflecting prism in each of the viewing-telescope systems is adjustable, so as to secure sharp focussing.

183153. Slater-Greenwood, W. VEHICLE LAMPS.

To reduce glare at will, an iris diaphragm, with crescent-shaped blades of mica or other translucent material, is placed within the lamp, and controlled from the dashboard.

183176. Curwen, J. S. COMPOSITE PICTURES.

A transparent line screen, formed of a series of convex strips, is placed in front of a composite picture, so that movement of the screen causes the picture to change. The size and positions of the parts is such that the screen, which is constituted, in effect, by a number of cylindrical lenses, produces such a magnification of the line elements of which the separate pictures are built up that from a given view-point the whole area appears to be filled. The movement necessary to produce a change of picture may be effected by the vibration of a railway carriage, or by the action of the wind; or a definite actuating-gearing may be fitted.

183242. Shuttleworth, J. P., and another. LEVELS.

A uniform circular tube, half filled with liquid, is mounted on the vertical face of a straight edge, which is provided with indicating marks.

183268. Rounce, E. GRINDING HOLLOW CYLINDERS.

The specification describes an attachment for a lathe, for the purpose of enlarging the bore of hollow cylinders. The grinding-wheel is driven through epicyclic gearing from a high-speed shaft passing through the hollow lathe-spindle, and it also receives a bodily eccentric movement, which is adjustable in extent.

183274. Terry, A. E. VEHICLE LAMPS.

An anti-dazzle attachment includes a number of open-ended tubes to direct the main beam, leaving an outer unobstructed margin to permit of the spreading of the indirect rays.

183571. Bentzon, M. GRINDING AND POLISHING LENSES.

Bi-focal lenses are made by grinding zones of different curvature by means of separate tools upon a disc, which is then cut up to form the lenses. The disc is secured to a rotating table, and brought up beneath the tools. The central area is ground by a tool which is rotated by a flexible shaft, and reciprocated between stops, while it is guided by a curved templet. The outer region of the disc is shaped by a second tool, also driven by a flexible shaft, its angular presentation to the disc being capable of variation so that a convex or concave curvature may be produced as desired.

183582. Frink, R. L. GLASS MANUFACTURE.

Metal moulds for glass-working are formed with porous or finely-pitted surfaces, as, for instance, by making them of an alloy of aluminium with 2 per cent. of calcium or barium, and then treating them with alkaline solutions.

183799*. Reichert, C. MICROSCOPES.

A microscope is fitted with both a monocular and a binocular body, either of which can be brought into use without moving the objective. The monocular and binocular tubes may be so connected that movement of the one brings the other into position, or a sliding prism may be fitted to direct the light as required.

183818. Gray, P. and Sons. SIGNAL LAMPS.

In addition to the main lamp, which is employed to give a coloured signal, a second source is fitted to give a clear light, and mask the effect of extraneous light, which, when reflected from within the lantern, might appear to constitute a signal. A clear sheet of glass, placed obliquely, acts as a reflector for the masking light, and also deflects some of the extraneous light entering the lantern.

183859. Wadsworth Watch Case Co. PHOTO-ETCHING.

A photographic etching resist or stencil is produced by projecting an image by an optical system upon a sensitive layer laid on the article to be treated, interposing an additional lens to produce a curvature of the image corresponding to that of the article itself.

183917. Gwilliam, F. G. LEVELS.

For levelling a line or cord, the level is pivoted to a base frame, to which one end of the line is anchored, while the other end passes over the pivot pin, and along the base of the level. When the line is drawn taut, the end may be raised or lowered to centre the bubble.

* Specification published before acceptance.

183936. Aldis, A. C. W. SIGHTING-TELESCOPES.

The image of a graticule, which is separately illuminated, is brought by an optical system of variable magnification into coincidence with the image of the field formed by the sighting system. In an instrument intended for anti-aircraft use, the variable magnification of the graticule system is obtained by the rotation of a sleeve having spiral slots in which the optical elements engage. Alternative eyepieces, of different powers, are mounted upon a rotating carrier.

184213. Proszynski, K. de. PROJECTION APPARATUS.

An electric lamp having its glowing filament near one side of the bulb is enclosed between two reflectors, one of which may form a water-jacket, and the other an air-jacketed door to the casing. One or both reflectors may terminate in the plane of the filament. In the larger one there is an aperture through which practically all the light is projected, either directly from the smaller reflector, or indirectly after reflection in the larger one.

184425. Simpson, A. CLEANING LENSES.

A device for cleaning, for example, spectacle lenses, consists of two arms pivoted together, each carrying a disc of chamois leather secured in position by adhesive.

184490*. Soc. d'Optique &c. de Haute Précision. HEIGHT FINDERS.

The apparatus consists of a range-finder having an arrangement of links and slides to indicate height, inclination and range, the centre of rotation of the system being co-axial with the range-finder.

184500. Coryell, W. C. GRINDING EDGES.

The edges of strips of glass are ground by feeding them obliquely against grinding-rollers, which are formed with hyperboloidal surfaces. The curvature produced upon the strip depends upon the angular presentation of the strip to the rollers.

184556. Holmes, J. F. GRINDING CYLINDERS.

The apparatus is designed for grinding the inside of hollow cylinders, and can be used either independently, or as an attachment to a lathe. The grinding-wheel is driven at high speed from a shaft fitted with universal joints, and carried through a tubular member, which can be previously adjusted by radial screws to the desired eccentricity relative to a rotating face-plate.

184611. Wallace, C. W. MEASURING ANGLES.

In connection with observations by compasses and sextants, angles are measured in terms of uniform graduations upon the chord of a quadrant. A pivoted radial cursor-arm carries an index web of sufficient length to intersect the graduated chord in all positions.

184645. British Thomson-Houston Co., Ltd. VEHICLE LAMPS.

The reflector consists of two paraboloids having a common focal plane and parallel, but not coincident, axes. The source of light is placed between the respective foci.

184728. Heath, G. A. SEXTANTS.

The "greatest angle" clamp is fitted with an indicator showing the true point of contact between the clamp and the radius-arm.

* Specification published before acceptance.

184853. Marks, E. C. R. PHOTOMETRIC APPARATUS.

One photo-electric cell, under the influence of a steady illumination, is connected to oppose the current in the grid circuit of an electron tube, while a second cell is connected in opposition to the first, so that changes in the current through the second produce an amplified effect upon the current in the main circuit. The apparatus described is arranged to test the colour of cigars by causing the light reflected from them to fall upon the second cell.

184908. Clarke, C. H. LENS MOUNTS.

The lens is secured to a spherical frustum which works within a similar frustum upon the support, means being provided to maintain the two parts in contact, while permitting the direction of the axis of the lens to be varied.

185109*. McLean, S. VEHICLE LAMPS.

The bulb is movable in a guide tube by means of a Bowden-wire mechanism, so as to put it in or out of focus.

185144. Tritsch, D. T. LARYNGOSCOPES.

This instrument can be readily dismounted for sterilising. The lamp and reflector screw upon the body, and also hold the tongue-piece, when it is not part of the body of the instrument. Current is conveyed through the handle by a plug connection.

185161. Procoudini-Gorsky, S. M. de. THREE-COLOUR APPARATUS.

The light from the object passes through a triple rhomboidal prism, which provides two partially-reflecting, partially-transmitting surfaces. These, together with the final reflecting surface, produce three beams of light, from which three identical images are formed by suitable lenses. The colour images are obtained by the use of the appropriate colour-filter with each lens.

185277. Barron, W., and another. ANNEALING-POTS.

Air is excluded by providing the pot with a double lid, and passing inert gas between the two portions. The articles are placed in a separate container within the pot.

185395*. Liesegang, E. PROJECTION APPARATUS.

Episcopic and diascopic systems are arranged upon opposite sides of the source of light. A movable reflector may be placed to cut off the light from either system at will, and reinforce the other.

185819. Tallack, H. T. SIGHTING-LEVELS.

The telescope is carried by a tube, which is rotated for adjustment in the vertical plane by a micrometer, the whole being mounted upon a spherical joint, capable of being screwed to a stand. The bubble tube is ground upon both its upper and lower surfaces, so that it can be used after reversal of the telescope.

185914. Sheringham, G. H. DAYLIGHT REFLECTORS.

Sunlight is modified by reflection from coloured surfaces, or by transmission through coloured media, so as to resemble ordinary north light.

186025. Tallack, H. T. LEVELS.

An opening is formed at one end of the metallic casing of a reversible bubble-tube, so that only one end of the bubble is exposed.

* Specification published before acceptance.

186038*. Richards, H., and others. VEHICLE LAMPS.

A coloured transparent envelope around the source of light is continuously rotated; or a parti-coloured bulb, rotated by a motor, is fitted.

186099. Zeiss, C., and another. BOMB-DROPPING SIGHTS.

The line of sight is displaced rearwardly by an amount dependent upon the air speed of the machine, and laterally by an amount determined by the speed and direction relative to the ground. A correction is also applied when the dropping-point does not coincide with the sighting-point. The sight is mounted upon a stabilised body, interchangeable sighting-scales being provided for use at different elevations.

186100. Knight, A. E. ILLUMINATED SIGNALS.

A signalling-device for motor vehicles includes two solenoids, so arranged in connection with the steering-wheel as to move one or other of two translucent signal plates into position before an aperture in an illuminated casing, a shutter being simultaneously removed. A similar arrangement may be employed in connection with the clutch or brake control.

186159. Vickers, Ltd., and another. INDICATING TURNING.

The precession movement of a gyroscope resulting from a turning motion of an aircraft controls a shutter, which exposes in succession a number of illuminated openings, and gives an indication of the direction and amount of the turning.

186160. Hilger, Ltd., A., and another. ANNEALING.

In annealing rods of glass, porcelain, or certain metals, the rod is subjected to a permanent stress while in the oven, means being provided to ascertain when yielding occurs.

186228. Greenwood, T. BEVELLING LENSES.

The flat face of an inclined grinding-wheel operates upon the edges of a number of lenses, which are rotated by separate spindles mounted upon a carriage. When treating circular lenses, the carriage is fixed, but in other cases it is oscillated by a suitable templet.

* Specification published before acceptance.

R. J. T.

NOTICE

THE INSTITUTE OF PHYSICS

Examination for the Associateship, 1923

NOTICE is hereby given that the Institute will hold its EXAMINATION of CANDIDATES for the Associateship in London at the latter end of September, 1923. Application for entry must be received before June 30th.

Forms of application and copies of the papers set in 1922 can be obtained from the Secretary.

Regulations for admission into the Institute without examination will also be sent on application.

By order of the Board,

F. S. SPIERS, *Secretary*.

10 Essex Street, Strand, W.C. 2.